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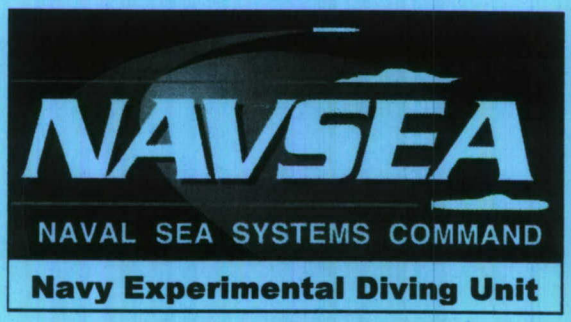
EVALUATION OF SELF-APPLIED TOURNIQUETS FOR COMBAT APPLICATIONS, SECOND PHASE



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19. ABSTRACT
In a repeated measures design, thirteen tourniquets for combat application were tested for their ease of use and ability to occlude arterial blood flow to the upper and lower extremities. To simulate field conditions, subjects completed an exercise routine and then applied a tourniquet that had been immersed in a blood analog solution and rolled in sand. Subjects applied the tourniquets while blindfolded and in seated or supine positions. Tourniquet evaluations were based on five parameters: failure rate, application time, occlusion efficacy (as determined by both Doppler and impedance plethysmography), and subjective evaluations. Results showed wide variations in tourniquet performance across the measured parameters. Inferential analysis and post-hoc group classifications allowed tourniquets to be stratified according to overall performance.

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INTRODUCTION

Mortality statistics from Operation Iraqi Freedom (OIF) indicate that deaths among U.S. forces are often not immediate but from hemorrhagic shock following the detonation of improvised explosive devices (IEDs). U.S. troops are currently equipped with Kevlar body armor and helmets that have decreased the number of fatalities resulting from penetrating chest wounds and serious head trauma, but the number of deaths attributable to extremity wounds has increased.[1] Evidence suggests that approximately 7% of these deaths could be prevented with the prompt application of an effective tourniquet.[2,3]

A wide range of objectives and methods have been used to test many candidate tourniquets. Although nearly all medical experts agree that the primary objective of any tourniquet device is to achieve hemostasis, no indirect methodological gold standard exists for assessing arterial occlusion distal to tourniquet placement. One evaluation of possible tourniquets for combat established the criterion that, to be considered successful, a tourniquet must result in no detectable blood flow (Doppler) in at least 75% of the subjects.[4] The U.S. Army Institute of Surgical Research, Fort Sam Houston, conducted a physiological assessment of the Army one-handed tourniquet (OHT) — an assessment that included use of occlusion plethysmography, a method thought to be more quantifiable than Doppler for determining blood flow. Its study demonstrated that a minimum of about 20% of baseline blood flow can be present in the absence of detectable Doppler blood flow. The researchers concluded that Doppler auscultation may overestimate the effectiveness of a clinical procedure (e.g., an applied tourniquet) designed to occlude blood flow and may underestimate the actual amount of blood flow present.[5]

This study also concluded that while the Army OHT is a welcome "first step" that can effectively minimize blood flow in the arm, it does not work in the lower extremities. This conclusion is particularly disturbing, since the majority of battlefield wounds requiring tourniquet application occur in the lower limbs.[6] The Army report attributed the OHT's inability to effectively stop leg blood flow to its relatively narrow one-inch width. Previous investigators have clearly demonstrated an inverse relationship between tourniquet width and the minimum pressure required to occlude arterial blood flow: as the width of a tourniquet decreases, the pressure required to occlude arterial blood flow increases.[7–9]

A Navy Experimental Diving Unit (NEDU) evaluation of five tourniquets in 2005 provided the groundwork for future tourniquet testing. The tourniquets evaluated were the Combat Application Tourniquet (CAT), the Mechanical Advantage Tourniquet (MAT), the OHT, the Quickette, and the Tourni-Kwik (TK). To better simulate field conditions in that trial, subjects were asked to complete a rigorous period of pretrial exercise. In addition to being fatigued and sweaty, subjects were then asked to apply a tourniquet that had been soaked in a blood analog solution and rolled in sand to determine the tourniquet's durability and ability to occlude blood flow when the site of its application was soaked with a slippery substance similar to blood. To further simulate field

conditions, the subject's ability to apply a tourniquet device during night simulation (blindfolded) was evaluated. Marine Corps Systems Command (MARCORSYSCOM) funded an objective for NEDU to field test the thirteen candidate tourniquets listed in Table 1 in a manner similar to that of the initial NEDU study.[10]

METHODS

GENERAL

Twenty-eight active duty Navy personnel served as test subjects. They applied the tourniquets over long-sleeved battle dress uniforms (BDUs) worn in each trial. Before each tourniquet application, subjects completed exercises to elevate their heart rates to a goal of 120 beats per minute while the tourniquets were immersed in a blood analog solution and then rolled in sand to simulate desert combat (field) conditions.

EXPERIMENTAL DESIGN

Combinations of tourniquets and extremities were tested in a repeated measures design based on the following parameters:

(1) mechanical and application failures;

(2) application times;

(3) flow versus no-flow, as measured by Doppler stethoscope;

(4) percentage circulatory occlusion, as measured by impedance plethysmography (IPG); and

(5) subjective ratings of tourniquets by test subjects.

For the purposes of this study, a mechanical failure is defined as a failure that occurred due to a malfunction of the materials from which a tourniquet is constructed or a design flaw that prevented successful application of the tourniquet. An application failure is defined as an application time exceeding five minutes. The application time was measured from the time the test subject began applying the tourniquet until the time the test subject declared application was completed.

Tourniquets were applied to two extremities:

- Upper extremity, approximately two inches above the elbow; and
- Lower right extremity, as close to the groin crease as possible.

During upper extremity trials, subjects used their nondominant hands to apply tourniquets to the opposite upper arm. This was done to simulate a worst-case scenario, one in which combatants would need to apply tourniquets to the upper extremity with their nondominant hands. Subjects were permitted to use both hands to apply tourniquets to the lower extremities.

A randomly generated test matrix was developed to prescribe which tourniquets each subject would apply on a given test day. Subjects occluded a given extremity only once on each test day, and a different test matrix was used for each subject to minimize potential order effects. The test matrix is shown in Appendix A.

This protocol was designed to detect a difference in the percentage of circulatory occlusion (10%) and application latency (30 seconds) with an estimated standard deviation (SD) of 5% and 25 seconds, respectively. For these parameter estimates, the anticipated statistical power for paired comparisons with $\alpha = .05$ is .80 with a sample size of 26.

TOURNIQUET DESCRIPTIONS

The 13 tourniquets tested are listed in Table 1 and shown in Figure 1. The tourniquets were divided into three categories according to their mechanisms of action: windlass, ratchet, and stretch-retention. Windlass types operate via a twisting action in which a bar is looped through the tourniquet material and twisted. Ratchet types function by a one-way locking device that pulls itself farther along a toothed track as the mechanism is actuated. Stretch-retention devices operate on the elastic properties of the device and are typically wrapped several times around the extremity. Tourniquet weights, dimensions, and mechanisms of action ordered by increasing weight are listed in Table 2.

Table 1.
Product Names, Acronyms, and Manufacturers of Tested Tourniquets

Product	Acronym	Manufacturer
Burke Device	Burke	Biomedical Innovations; Southern Pines, NC
Combat Application Tourniquet	CAT	North American Rescue Products; Greenville, SC
Flow Stopper Tourniquet	FST	Creative & Effective Technologies Inc; Raeford, NC
Mechanical Advantage Tourniquet	MAT	Bound Tree Medical; Henniker, NH
McMillan Tourniquet	McMill	CSM Tactical Gear; Temecula, CA
Military Emergency Tourniquet	MET	ATSCC; Virginia Beach, VA
NATO Tourniquet	NATO	Deployment Medical Resources; Partlow, VA
One-Hand Tourniquet-2" width	OHT-2	Canvass Specialties, Inc.; San Antonio, TX
Q-Tourniquet	Q	Blade Tech Industries; Lakewood, WA
Special Operations Forces Tactical Tourniquet	SOFT-T	Tactical Medical Solutions; Anderson, SC
TIAX Tourniquet	TIAX	TIAX, LLC; Cambridge, MA
Tourni-Kwik-3	TK-3	H & H Associates; Bena, VA
Tourni-Kwik-4	TK-4	H & H Associates; Bena, VA

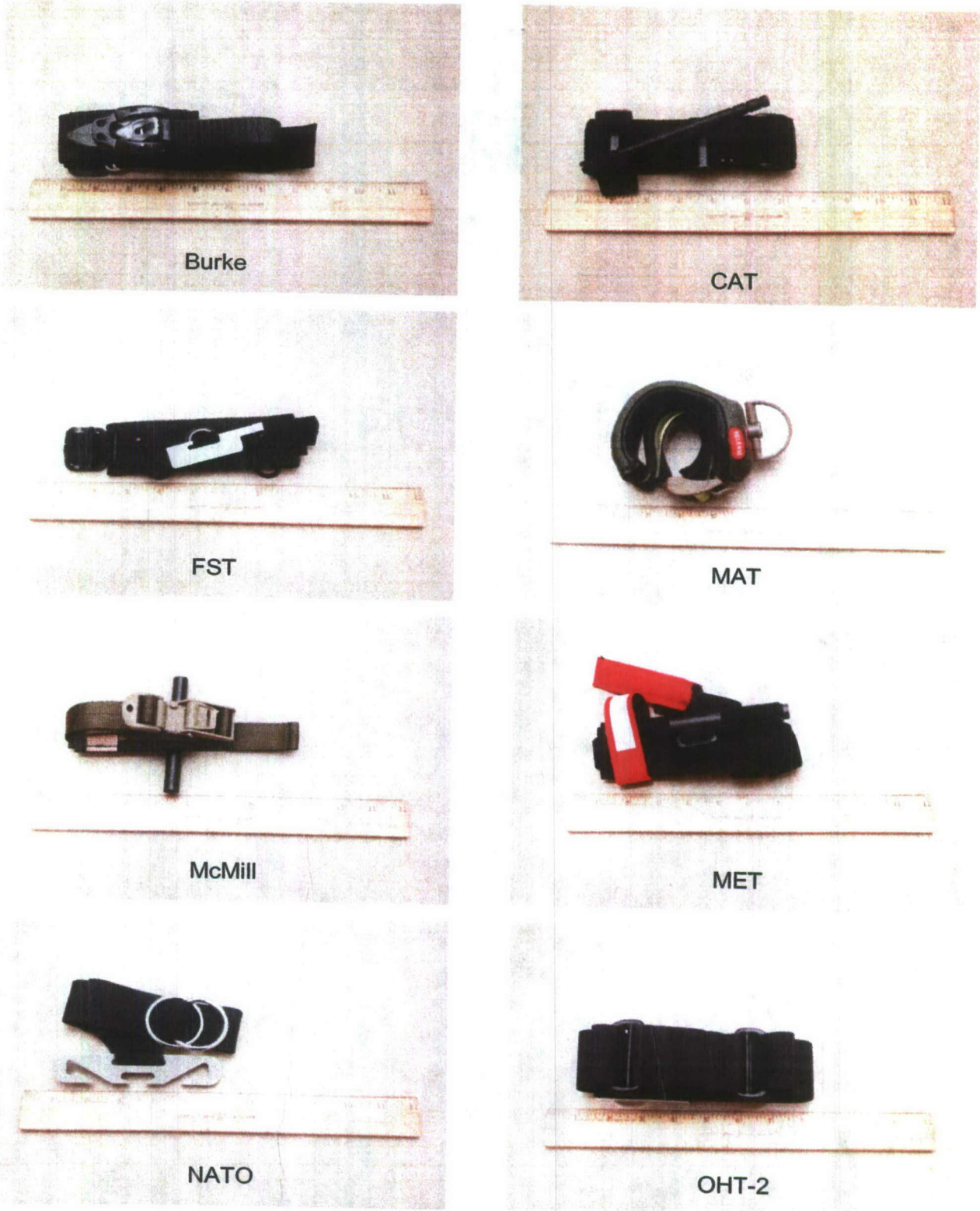

Figure 1. Tourniquets tested in the present work.

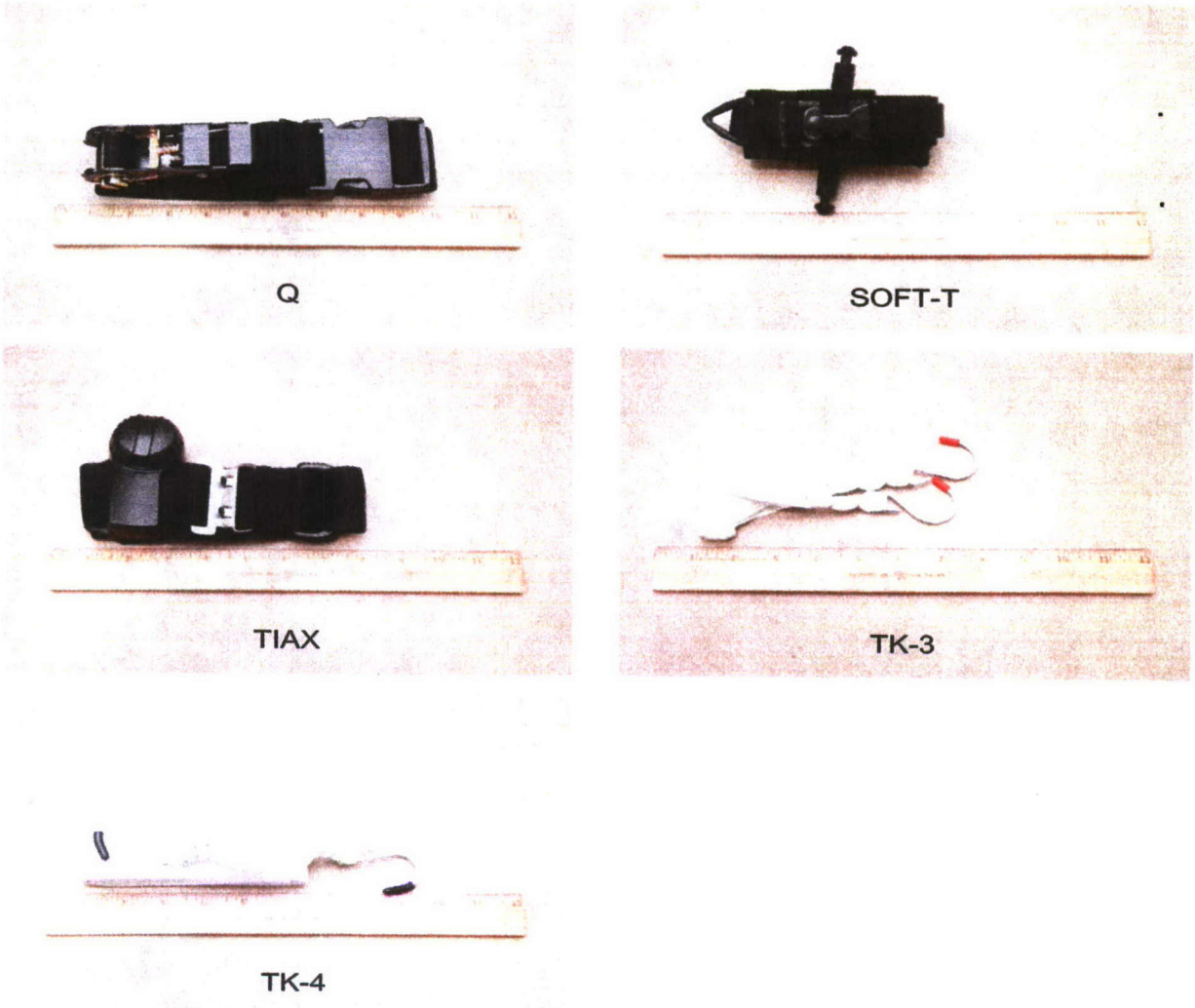

Figure 1, cont. Tourniquets tested in the present work.

Table 2.
Tourniquet Weights, Dimensions, Volumes, and Mechanisms of Action, in Order of Increasing Weight

Tourniquet	Weight (grams)	Volume (cm^3)	Dimensions (cm)	Mechanism
TK-3	42.3	113.5	8.9 x 2.5 x 5.1	Stretch-retention
TK-4	53.1	250.6	6.4 x 4.4 x 8.9	Stretch-retention
CAT	62.3	413.8	16.5 x 4.4 x 5.7	Windlass
FST	87.4	243.5	19.1 x 5.1 x 2.5	Windlass
NATO	97.2	271.3	14.0 x 5.1 x 3.8	Windlass
MET	113.1	345.0	17.8 x 5.1 x 3.8	Windlass
MAT	114.6	705.0	10.2 x 6.4 x 10.8	Ratchet
Burke	116.8	319.8	16.5 x 5.1 x 3.8	Ratchet
McMill	119.0	351.7	12.1 x 5.7 x 5.1	Windlass
OHT	120.9	386.6	13.3 x 5.1 x 5.7	Stretch-retention
SOFT-T	126.0	457.0	14.0 x 5.1 x 6.4	Windlass
TIAX	158.5	581.0	10.2 x 8.9 x 6.4	Ratchet
Q	328.7	681.0	14.0 x 7.6 x 6.4	Ratchet

EQUIPMENT AND INSTRUMENTATION

Tourniquet efficacy was assessed by the presence or absence of arterial blood flow, as measured with an ultrasonic Doppler stethoscope (MedSonics #FP3A). The percentage of arterial occlusion was measured with tetrapolar electrical impedance plethysmography (IPG). IPG waveforms were measured with a Tetra-polar High Resolution Impedance Meter (THRIM) Model #2992D (UFI; Morro Bay, CA) and recorded in real time for later analysis with electrocardiograms (ECGs) that were simultaneously acquired with a UFI Model 2121 Ambulatory ECG Bioamplifier (UFI; Morro Bay, CA). 3M™ Red Dot™ 2237 Monitoring Electrodes (3M; St. Paul, MN) were used for both the IPG and ECG applications. Electrode placement for IPG measurements on the two right extremities is illustrated in Figure 2. Electrocardiograms were acquired with electrodes positioned in a standard 3-lead ECG placement configuration. Doppler stethoscope probe placement for monitoring each extremity was marked on each subject at the beginning of each test day.

IPG, ECG, and Doppler analog signals for the monitored extremity were passed through a DI-706 Interface (DATAQ Instruments; Akron, Ohio) to a DI-720 Analog-to-Digital converter (DATAQ Instruments; Akron, Ohio), where they were digitized at a sampling rate of 250 Hz per channel for recording with WinDaq/Professional Waveform Recording Software (DATAQ Instruments; Akron, Ohio) on a laptop computer. After each test, limb blood flows were determined from the recorded IPG waveforms with a custom program, Rheoencephalographic Impedance Scanning System (RheoSys), developed by LDM Associates. A description of the methodology used and the program procedures are included in Appendix B.

The blood analog solution consisted of a mixture of five parts water with three parts Dowfrost® propylene glycol antifreeze concentrate (Hubbard-Hall Inc.; Waterbury, CT). The final mixture had a viscosity of about 3.2 centipoise at room temperature, approximately equal to that of whole blood at a physiological hematocrit of 45 percent.[11–13]

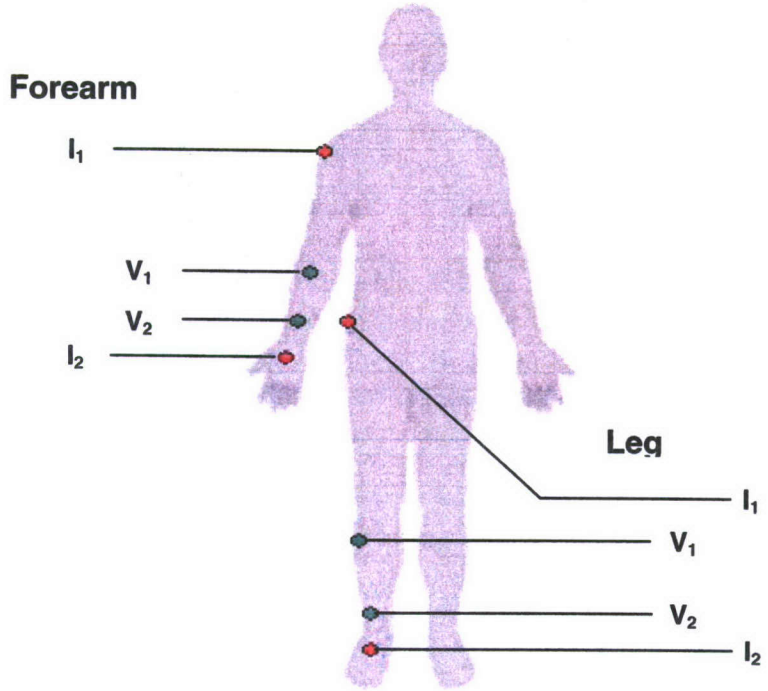

Figure 2. Electrode placements for IPG measurements on right extremities. On each extremity the voltage developed in response to a current (0.8 mA, 50 kHz) passed between electrodes I_1 and I_2 was passively measured across electrodes V_1 and V_2.

PROCEDURES

Training

NEDU medical department personnel briefed test subjects on the proper use of each tourniquet per the manufacturer's instructions.[14–25] Following each brief, subjects practiced applying the tourniquet to the appropriate extremities. After medical personnel verified that the tourniquet had been correctly applied during the practice application, the tourniquet was removed and any questions the test subjects had were addressed.

Pretest Tourniquet Preparation

Using the appropriate tourniquet determined by the test matrix for each subject, investigators prepared a new tourniquet for each trial. Immediately before a tourniquet was handed to a subject for testing, it was removed from its packaging, fully immersed in a blood analog solution, and rolled in sand.

Pretest Exercise and Tourniquet Application

Each subject was fitted with IPG and ECG electrodes at the beginning of each test day. Electrode sites were wiped with alcohol and allowed to dry before electrodes were applied, but the sites were not abraded or shaved. Tourniquets were applied over long-sleeved battle dress uniforms (BDUs) made of 50% nylon/50% cotton Ripstop fabric (American Apparel Incorporated). The BDUs were worn by each subject throughout the trials.

Each trial proceeded as follows: subjects completed a pretrial regimen that consisted of various exercises with a goal of elevating heart rate above 120 beats per minute. Immediately after completing this exercise regimen, the subject assumed a supine position on the floor for testing and was blindfolded while electrode cables were threaded under the BDU and connected to the monitoring electrodes. The subject was then asked to remain still while baseline data was collected. At the end of this period a technician handed the subject the test tourniquet prepared with sand-impregnated blood analog solution. This event, indicated in the record by a single event mark, was the beginning of the application time period. While remaining supine or after assuming a seated position on the floor, the subject began applying the tourniquet to the selected extremity (upper arm or thigh).

Applications to arms were performed one-handed, but use of both hands was allowed for applications to thighs. A maximum of 5 minutes was allowed to apply the tourniquet, after which time the trial was terminated as an "application failure." Application of the tourniquet was successful if the subject vocally declared, "Tourniquet on" — indicating that he had reached a point just before continued tightening would produce unbearable pain and had secured the device — within 5 minutes of being handed the test tourniquet. Upon such a declaration, a double event mark was recorded to mark the end of the application time period. The subject was asked to remain still throughout the remainder of the procedure.

As soon as possible following tourniquet application, a technician positioned the Doppler probe and made a "flow" or "no-flow" call based on the auditory output from the Doppler stethoscope. IPG measurements were continued, with the tourniquet applied for a period limited to a maximum of 60 seconds. The technician then released the tourniquet, and a triplet of event marks was entered into the record to mark the time of tourniquet release. Final sets of Doppler and IPG measurements were completed to confirm that circulation had been restored, and the distance from the anterior superior iliac crest to the top of the tourniquet application site was measured for lower extremity applications. While resting for 10 minutes, the subject then dictated any comments about the tourniquet into a handheld tape recorder. Using the appropriate tourniquet from the test matrix, the subject repeated this sequence for the other extremity.

At the conclusion of the last testing day for each subject, each was asked to rank the thirteen tourniquets on the basis of his subjective impressions of its user friendliness, ease of application while the user was blindfolded, and comfort. The rank *R* ascribed by

a subject to a given tourniquet ($R = 1$ "Best"; $R = 13$ "Worst") was converted into a Score = $(N+1) - R$, where $N = 13$ was the number of tourniquets.

DATA ANALYSIS

Failure rate was analyzed for each tourniquet to include mechanical and application failures. Mean application times and SDs for both upper and lower extremity applications were measured and recorded. Percentages of no-flow for each tourniquet for upper and lower extremities were calculated for all tourniquets.

Three segments from the overall IPG record for each trial were extracted into separate WinDaq files for analysis.[26] Exact locations of these segments in different trials varied depending upon the quality of the recorded data, but data were extracted according to the following rules:

START = Pulse sequence nearest the end of the baseline period.

END = Pulse sequence after the subject had declared that the tourniquet was fully applied and before the tourniquet was released.

POST = Pulse sequence after the tourniquet was released near the end of the test run.

The appropriate "START," "END," or "POST" designation was included in the filename of the extracted WinDaq file, and in the various tabulated data sheets, to denote the analyzed segment of the test. Data from the segments for each trial were analyzed as described in Appendix B. Mean percentage occlusion, median percentage occlusion, SD, and percentage of trials with increased flow were analyzed for all tourniquets and for both upper and lower extremities.

Inferential analysis of all results progressed sequentially. The null hypothesis for all tests was no difference among any of the tourniquets. All testing was performed with the R statistical package.[27] First, the appropriate analysis of group variance was completed. All group analyses were interpreted with 12 degrees of freedom (DF = 12). If this analysis showed a significant difference ($p<0.05$), a posttest multiple comparisons analysis to elaborate the differences between individual tourniquets was performed. Where appropriate, tests using pooled SDs and the Holm method of posttest comparisons were conducted.[27]

RESULTS

GENERAL

Although the trial was initially designed to have 26 test subjects, by the end of the trial 28 test subjects had been enrolled: two additional subjects had been enrolled following dropouts by two subjects for reasons not related to the tests. Of the 28 test subjects enrolled, 25 were able to complete the entire test matrix — a rate resulting in 25 complete sets of data, one less than desired. To maintain pairing for statistical analysis

and avoid introducing bias, 43 trials from the three subjects who did not complete the series were not analyzed. This yielded 50 applications of each tourniquet tested, a total of 650 trials. For upper extremity applications, one test subject was unable to apply tourniquets with his nondominant hand because an injury (unrelated to study participation) had occurred to that hand. The following parameters were measured for each of the tourniquets:

(1) mechanical and application failures;

(2) application times;

(3) flow versus no-flow, as measured by Doppler stethoscope; and

(4) percentage of circulatory occlusion, as measured by IPG.

Application times, Doppler flow, and percentage of circulatory occlusion were further subdivided into results for upper and lower extremity applications.

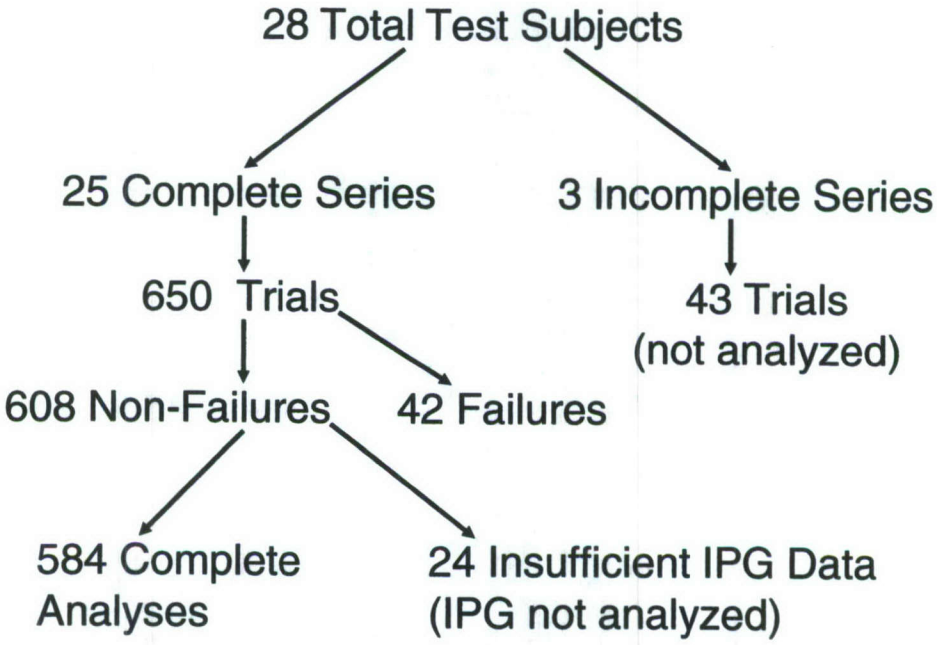

Figure 3. Breakdown of tourniquet trials. Three incomplete series yielded 43 trials that were not analyzed. Of the 650 trials analyzed, 24 had insufficient IPG data.

MECHANICAL AND APPLICATION FAILURES

Mechanical failures occurred in 36 trials. Application failures occurred in 6 trials. The numbers of applications and failures for each tourniquet are presented in Table 3. The nature of each mechanical failure is described in Appendix C. Inferential analysis of the failure data with the χ^2 test for multiple groups showed a significant difference in the data set ($\chi^2 = 45.7668$, $p<0.001$). A pair-wise test for paired proportions showed that the TIAX had a significantly higher failure rate than all other tourniquets ($p=0.0174$).[27] The remaining tourniquets had no differences in failure rate.

Table 3.
Number of Tourniquet Applications (n) and Failures

Tourniquet	n	Failure Type		% Failures
		Mechanical	Application	
FST	50	1	0	2
MET	50	1	0	2
TK-4	50	1	0	2
CAT	50	2	0	4
MAT	50	2	0	4
OHT-2	50	2	0	4
Q	50	2	0	4
Burke	50	3	0	6
NATO	50	2	1	6
SOFT-T	50	1	2	6
McMill	50	1	3	8
TK-3	50	4	0	8
TIAX	50	14	0	28

APPLICATION TIMES

It is important to note that the application times in this report do not include time needed to retrieve the tourniquet from stowage and remove it from its packaging, because testing required that it be soaked in blood and sand before application. Thus, the present application times underestimate the total time required in the field to retrieve and apply any of the tourniquets. Mean application times for each tourniquet are presented in Tables 4 and 5 below.

Table 4.
Upper Extremity Application Times

Tourniquet	Number of Trials	Mean application time (sec)	Standard Deviation (sec)
OHT-2	24	57.6	22.1
Burke	24	59.9	15.9
MAT	25	60.7	31.0
TK-3	24	70.4	27.6
Q	23	72.3	34.0
TK-4	25	72.8	33.9
TIAX	16	83.9	27.3
FST	25	95.1	38.3
CAT	25	97.1	37.8
MET	25	100.9	43.5
SOFT-T	22	129.6	74.5
NATO	23	138.9	60.7
McMill	22	161.4	78.8

Table 5.
Lower Extremity Application Times

Tourniquet	Number of Trials	Mean application time (sec)	Standard Deviation (sec)
OHT-2	24	41.8	18.5
MAT	23	46.6	12.0
Burke	23	48.8	21.5
Q	25	53.7	16.1
MET	24	54.1	23.8
TK-3	22	54.2	16.9
SOFT-T	25	56.3	25.2
CAT	23	57.9	28.6
FST	24	60.7	22.0
TK-4	24	65.3	32.5
NATO	24	71.4	31.7
TIAX	20	75.0	32.4
McMill	24	89.9	39.2

Except for the mechanical and application failures enumerated in Table 3, subjects were able to apply the tourniquets to extremities within 14 to 279 seconds for upper extremities and 14 to 175 seconds for lower extremities. Analysis of variance (ANOVA) of the applications times showed significant differences for both upper ($F = 13.104$, $p<0.001$)

and lower ($F = 5.9836$, $p<0.001$) extremities. Posttest analysis by pair-wise comparisons with t-tests using pooled SDs defined the significant differences in application times among the tourniquets. The p-values from this analysis are provided in Appendix D, Tables D-1 and D-2.[27] For upper extremity application times the SOFT-T, NATO, and McMillan were significantly different from the majority of the other tourniquets. For lower extremity application times only the McMillan was different from the majority of other tourniquets.

DOPPLER FLOW MEASUREMENTS

Data from a total of 608 trials/applications were included in the Doppler analyses. These trials were assigned either an outcome of positive or negative to indicate a flow versus a no-flow call. These outcomes were determined solely by the operator using a Doppler stethoscope. Applications were further subdivided into upper and lower extremity measurements. The percentages of trials resulting in Doppler no-flow calls for all tourniquets for both upper and lower extremities are provided in Tables 6 and 7 and in Figures 4 and 5.

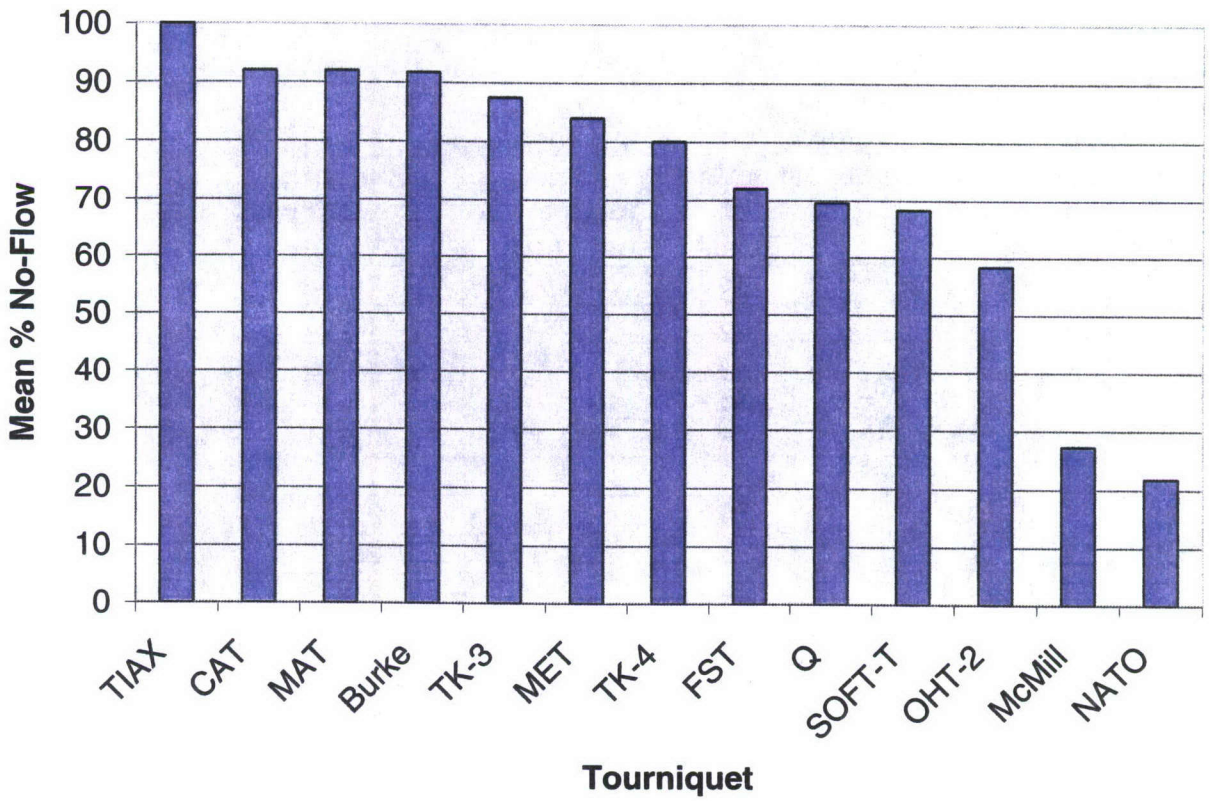

Figure 4. Mean percentage no-flow for upper extremity trials, as measured by Doppler.

Table 6.
Upper Extremity Doppler Data

Tourniquet	Number Analyzed	Number No-flow	% No-flow
TIAX	16	16	100.00
CAT	25	23	92.00
MAT	25	23	92.00
Burke	24	22	91.67
TK-3	24	21	87.50
MET	25	21	84.00
TK-4	25	20	80.00
FST	25	18	72.00
Q	23	16	69.57
SOFT-T	22	15	68.18
OHT-2	24	14	58.33
McMill	22	6	27.27
NATO	23	5	21.74

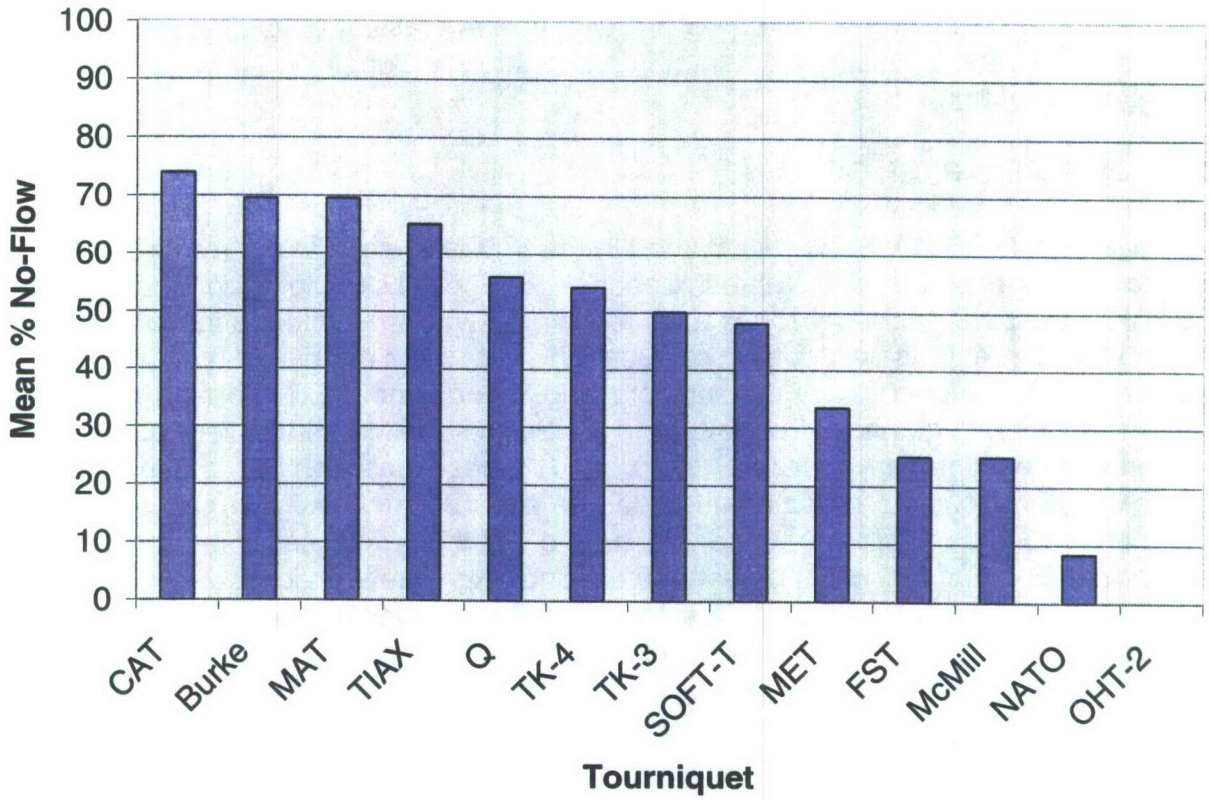

Figure 5. Mean percent no-flow for lower extremity trials, as measured by Doppler.

Table 7.
Lower Extremity Doppler Data

Tourniquet	Number Analyzed	Number No-flow	% No-flow
CAT	23	17	73.91
Burke	23	16	69.57
MAT	23	16	69.57
TIAX	20	13	65.00
Q	25	14	56.00
TK-4	24	13	54.17
TK-3	22	11	50.00
SOFT-T	25	12	48.00
MET	24	8	33.33
FST	24	6	25.00
McMill	24	6	25.00
NATO	24	2	8.33
OHT-2	24	0	0.00

Inferential analysis of the Doppler data with the χ^2 test for multiple groups showed a significant difference in the data set for both upper ($\chi^2 = 80.3122$, $p<0.001$) and lower ($\chi^2 = 66.4944$, $p<0.001$) extremities. A pair-wise comparison test for proportions was performed. P-values are reported in Appendix D, Tables D-3 and D-4.[27] For upper extremities, the NATO and McMillan tourniquets significantly differed from the majority of the other tourniquets in percentage of Doppler no-flow calls. For lower extremities, only the OHT-2 was significantly different in percentage of Doppler no-flow calls from the majority of tourniquets.

IMPEDANCE PLETHYSMOGRAPHY

Data from a total of 584 trials were included in the IPG analyses. Data from a given trial were included if they had fairly stable impedance, ECG, and Doppler recordings in both the START and END sequences. Data from a given trial were excluded if impedance, ECG, or Doppler records were lost or corrupted by excessive motion artifact during START or END sequences, or if the subject failed to complete application of the tourniquet. A tracing gathered from a tourniquet trial completed under ideal laboratory conditions can be seen in Appendix B, Figure B-1. These ideal conditions and data tracings were not consistently obtained under the experimental design of this study. While many IPG data tracings obtained during the test trials were easily interpreted, significant motion artifact typical of that seen during tourniquet application — especially when there was not a good return to a smooth resistance tracing during the postanalysis period — resulted in data that could not be interpreted, as noted in the 24 trials with insufficient IPG data (Figure 3).

Analysis of IPG data indicated an apparent increase in blood flow in 148 trials. Of those, 53 were for upper extremity applications, and 95 were for lower extremity applications. Figures 6 and 7 illustrate the mean percentages of arterial occlusion achieved in the upper and lower extremities with the tourniquets fully applied, as indicated by IPG. Tables 8 and 9 present the number of each tourniquet analyzed, mean percentage occlusion, median percentage occlusion, standard deviation, and percentage of trials with increased flow for each tourniquet applied to upper and lower extremities. Table 9 also includes mean distance (cm) as measured from the top of the anterior superior iliac crest to the top of tourniquet placement area for lower extremity trials.

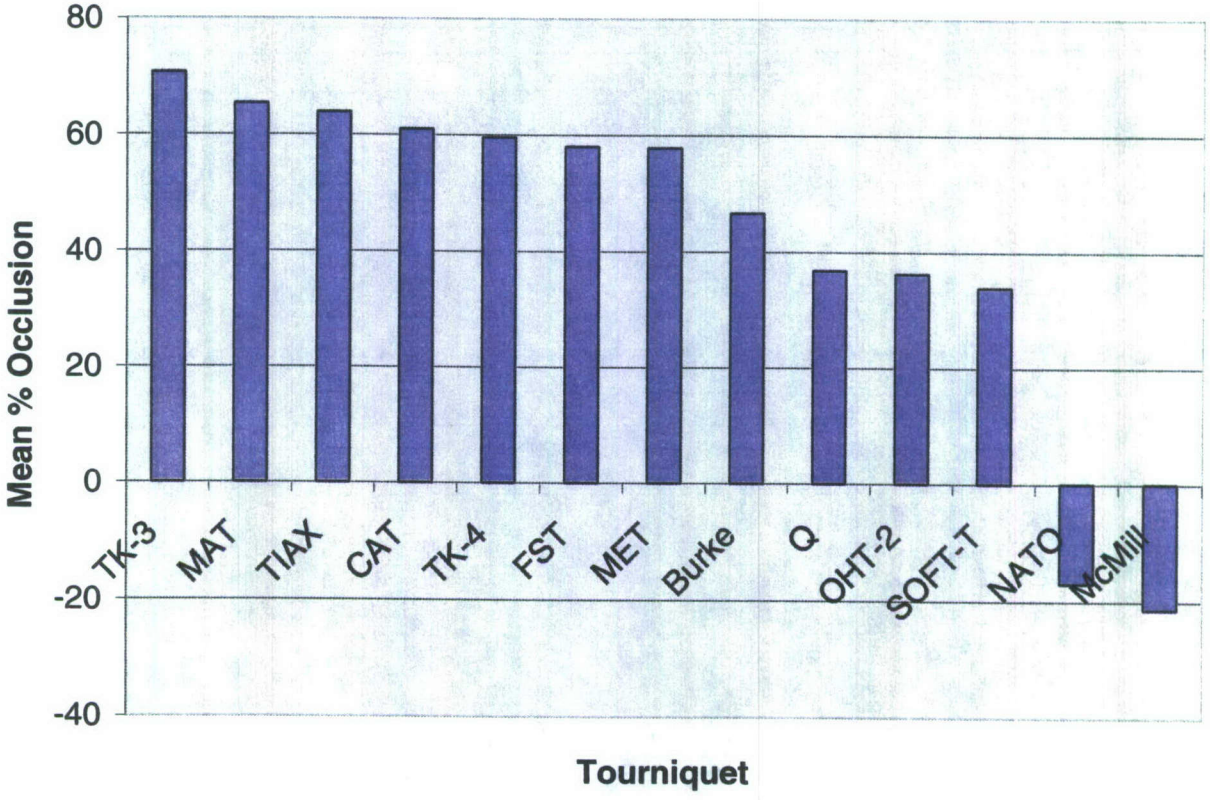

Figure 6. Mean percentage occlusion for upper extremity trials, as measured by IPG.

Table 8.
Upper Extremity IPG Data

Tourniquet	Number Analyzed	Mean % Occlusion	Median % Occlusion	Standard Deviation % Occlusion	% Trials Increased Flow
TK-3	21	70.58	80.93	22.30	0.00
MAT	25	65.22	85.56	46.05	8.00
TIAX	16	63.82	75.85	33.61	0.00
CAT	22	60.95	71.60	41.78	9.09
TK-4	24	59.54	67.67	34.75	8.33
FST	24	58.05	73.72	47.23	12.50
MET	21	57.83	80.59	48.33	12.50
Burke	24	46.58	64.80	50.26	25.00
Q	22	36.77	46.43	54.85	22.73
OHT-2	22	36.26	58.63	64.89	13.64
SOFT-T	21	33.74	64.82	70.00	28.57
NATO	20	–16.88	–5.25	87.34	60.00
McMill	22	–21.41	12.17	105.78	40.91

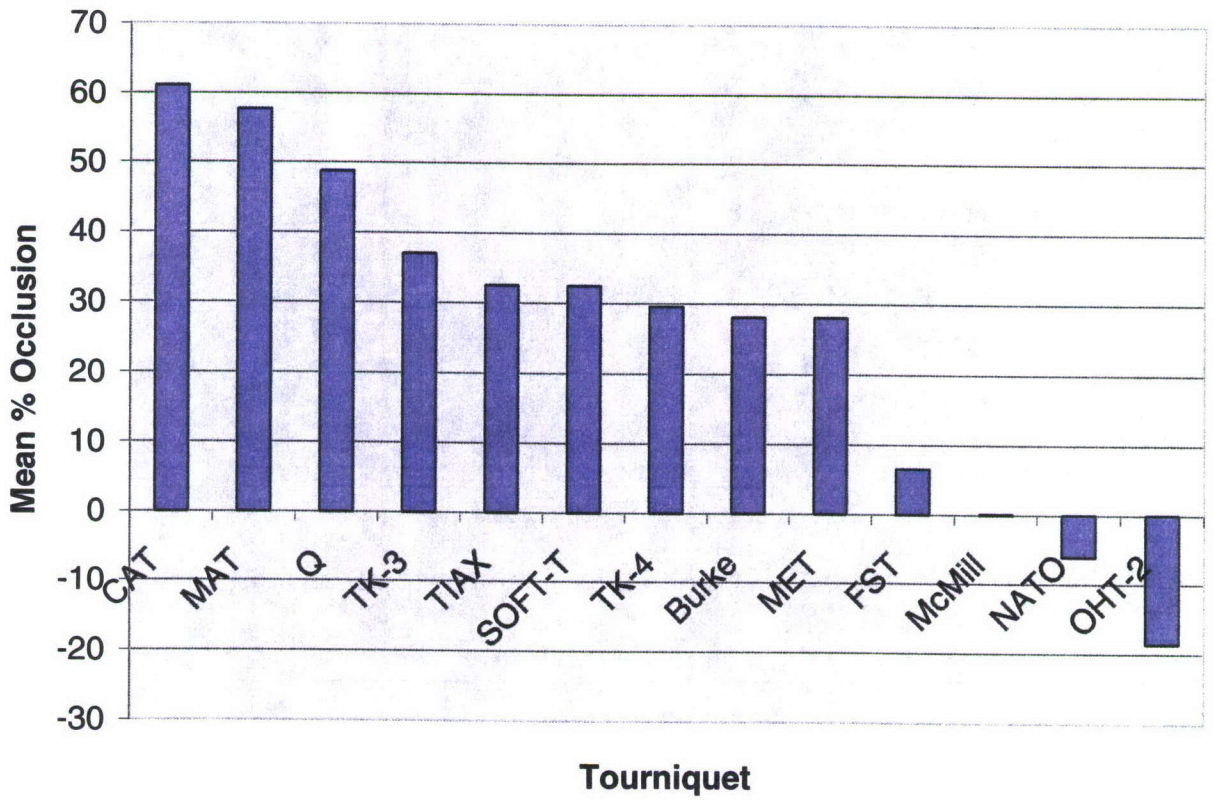

Figure 7. Mean percentage occlusion for lower extremity trials, as measured by IPG.

Table 9.
Lower Extremity IPG Data

Tourniquet	Number Analyzed	Mean % Occlusion	Median % Occlusion	Standard Deviation % Occlusion	% Trials Increased Flow	Mean Distance (cm)
CAT	22	61.08	70.49	39.19	13.64	25.2
MAT	22	57.67	72.55	43.53	9.09	25.0
Q	25	48.69	64.16	44.13	12.00	24.6
TK-3	20	36.95	55.56	49.43	40.00	25.3
TIAX	18	32.48	60.76	58.66	27.78	26.4
SOFT-T	24	32.45	50.82	56.26	37.50	25.1
TK-4	24	29.53	54.71	67.99	33.33	27.0
Burke	23	28.04	57.86	100.23	17.39	24.7
MET	23	28.02	20.28	51.92	17.39	23.7
FST	24	6.45	9.55	57.45	37.50	26.5
McMill	24	0.10	5.89	54.77	45.83	28.1
NATO	24	–6.10	–1.46	42.14	54.17	25.8
OHT-2	24	–18.60	–15.85	52.68	66.67	27.0

ANOVA of the IPG results showed significant differences for both upper ($F = 5.5336$, $p<0.001$) and lower ($F = 4.1672$, $p<0.001$) extremities. Posttest analysis by pair-wise comparisons with t-tests using pooled SD defined the significant differences in IPG results among the tourniquets. The p-values from this analysis are provided in Appendix D, Tables D-5 and D-6.[27] For the upper extremity, the NATO and McMillan were significantly different from the majority of the other tourniquets. For the lower extremity, no tourniquet was different from the majority of other tourniquets.

SUBJECTIVE RATINGS

At the conclusion of the present study, subjects ranked the 13 tourniquets according to their subjective impressions of user friendliness, ease of application while users were blindfolded, and comfort. The sums of the scores given for each tourniquet by the 25 individual subjects are shown in Figure 8.

Analysis of the subject ratings was completed with a Friedman's test, which showed a strongly significant difference among the group ratings ($\chi^2 = 124.3253$, $p<0.001$). This was followed by a pair-wise comparison using the Wilcoxon signed rank sum test for paired ordinal data. The p-values for this analysis are provided in Appendix D, Table D-7.[27] The subject ratings of the SOFT-T and FST significantly differed from those of the majority of the other tourniquets. The NATO was rated significantly lower than all other tourniquets. The MAT was rated statistically significantly higher than all but two other tourniquets.

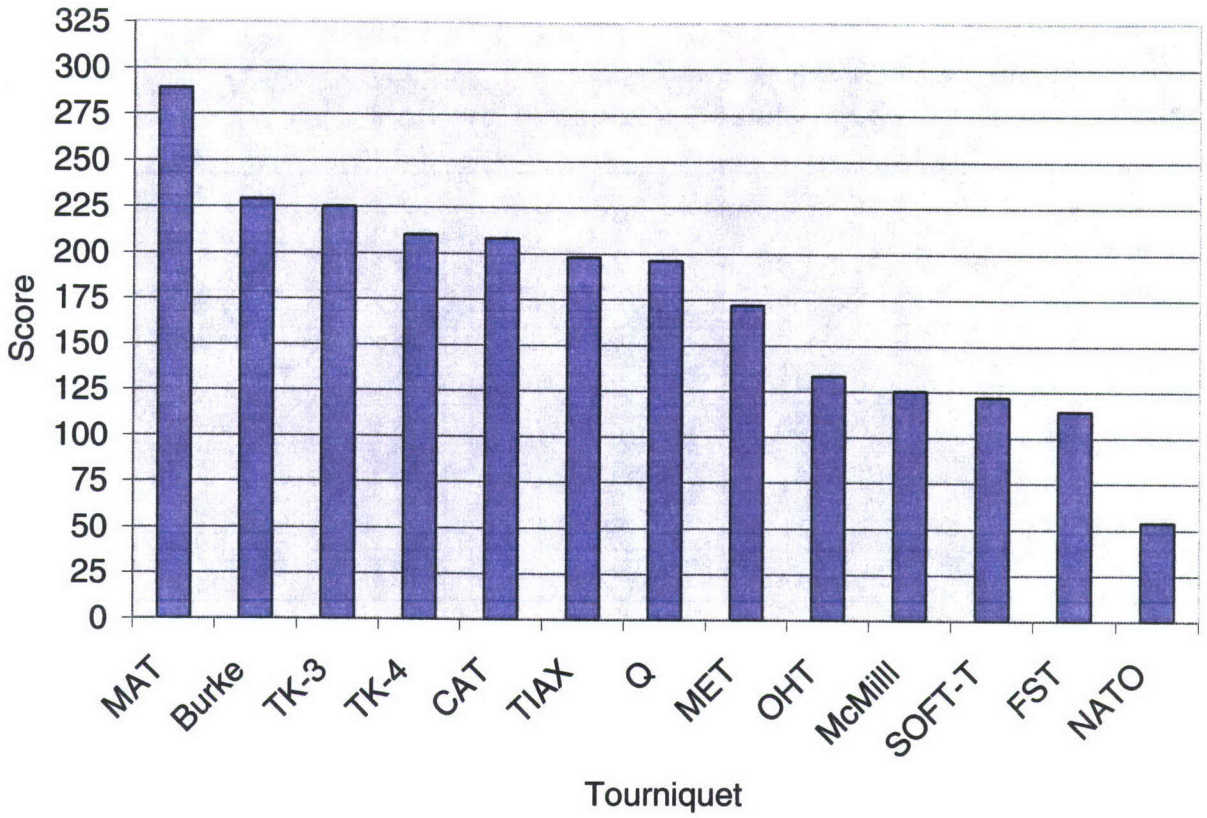

Figure 8. Totals of subjective rank scores assigned to the 13 tourniquets evaluated by the test subjects. Maximum possible score is 325.

DISCUSSION

GENERAL

Initial study design involved the participation of 26 test subjects, and a total of eight parameters were measured for each tourniquet. Two additional subjects were enrolled due to subject dropout. Of those two additional subjects, one of them also withdrew from the study. All of the subject dropouts were due to issues unrelated to the tests. Of the 28 total test subjects enrolled, 25 were able to complete the entire test matrix; this resulted in 25 complete sets of data, one less than originally anticipated. To maintain pairing for statistical analysis and to avoid introducing bias, 43 trials were not analyzed. Of the 25 completed sets (650 trials), 42 trials resulted in mechanical or application failures, and 24 had insufficient IPG data to be analyzed. This insufficient data was unobtainable due to electrode nonadherence, inability to obtain steady IPG tracings, or other technical factors. The percentage of IPG data lost (4%) was less than that in the previous tourniquet evaluation performed at NEDU (15%).[10] This difference in data loss does not consider the quality of individual tracings, only the number that was analyzed overall. Because the SD of application times and the results of IPG percentage of occlusion were much higher than estimated, and because only 25 subjects completed the trial, the power of the study did not approach the desired value.

MECHANICAL AND APPLICATION FAILURES

The number of applications and failures for each tourniquet are presented in Table 3. Mechanical failures occurred in 36 trials, and the nature of each such failure is described in Appendix C. Results clearly indicate that all tourniquets except the TIAX had low overall rates of mechanical failure. The TIAX had an unacceptably high mechanical failure rate (28%). This failure rate was significantly worse than those of all other tourniquets. Although the manufacturer's instructions state that the crank can be turned either clockwise or counterclockwise,[24] the majority of these failures — which occurred when test subjects turned the crank counterclockwise vice clockwise — resulted from the crank housing becoming separated from the tourniquet fabric. It is unknown how the rate of failure would have been affected if all TIAX devices had been turned clockwise, but it likely would have been lower than 28%.

Application failures, as shown in Table 3, occurred in six trials. All of these failures occurred with windlass tourniquets, a fact that is likely due to the inherent difficulty of securing such tourniquets. It is unclear whether occlusion was achieved before these failures, because Doppler and IPG determinations were not made until the subject stated that the tourniquet had been applied.

It should also be noted that although the TK-3 and TK-4 are essentially of the same design, the raw failure rates (8% versus 2%) of the two devices revealed a difference. This was not statistically significant; however, this difference is likely due to the stronger material with which the TK-4 is constructed as well as to the larger retaining rings that attach the hooks on the TK-4 to the tourniquet fabric and the addition of a third retaining ring.

APPLICATION TIMES

It is important to note that application times do not include the time required to retrieve the tourniquet from stowage and remove it from its packaging. Thus, the present application times underestimate the total time required in the field to retrieve and apply any of the tourniquets. In addition, it is important to preload tourniquets in order to decrease application time; however, this preloading could possibly increase risk for mechanical failure resulting from exposure to elements (direct sunlight, dust, etc). Intuitively, fine sand or dust in a Velcro closure decreases the strength of its adherence, and direct exposure to sunlight or heat can cause rubber and plastic components to degrade over time. These are all important complications that should be considered in the tourniquet selection process; however, these factors were not evaluated in this study.

As with any piece of lifesaving equipment, it is important that the user be proficient in applying the tourniquet: the greater the user's proficiency, the better his chance of a successful application. Clinically relevant application times are not well defined, but a reduced application time should result in improved outcomes due to an earlier arrest or a decrease of life-threatening hemorrhage. As such, it is critical that users be trained in

properly applying the tourniquet they are using before they use that tourniquet in a real life setting. Training will enable the user to apply the tourniquet more quickly and will increase the chances of its being applied properly.

Tourniquet application times varied widely, a result that is likely related to many variables including limited training of subjects, blindfolding of subjects during tourniquet application, and tourniquet fouling with sand-impregnated blood analog solution before application. As expected, lower extremity applications were overall quicker than those for the upper extremity, because the test subjects could apply their tourniquets with both hands. It is expected that added training would have reduced the variance and overall mean of application times.

Except for the mechanical and application failures enumerated in Table 3, subjects were able to apply the tourniquets to extremities within a reasonable amount of time (range: 14 to 279 seconds for upper and 14 to 175 seconds for lower extremities). If the tourniquets did not fail by mechanical malfunction, the majority of trials were completed with tourniquet application times of three minutes or less. No reliable trends in mean application times were observed over test days. The previous NEDU tourniquet study demonstrated that subjects were able to successfully apply tourniquets to the upper extremities irrespective of hand dominance.[10]

For upper extremity applications, it is interesting to note that the six windlass-type tourniquets took longer to apply than all others. This finding is highlighted by the fact that the SOFT-T, NATO, and McMillan statistically performed significantly worse than the majority of the other tourniquets. This trend was also observed on the lower extremity applications; however, it was not as clearly correlated as with upper extremity applications. For lower extremity applications, the TIAX performed worse than several other tourniquets — a result that does not follow the previously mentioned trends, since the TIAX uses a ratcheting system. This result is likely due to the excessive number of crank turns required to tighten the tourniquet.

DOPPLER FLOW MEASUREMENTS

Doppler is a commonly used indicator of significant blood flow, but it is an indirect measurement of such blood flow. A Doppler no-flow call does not guarantee absence of blood flow. Doppler measurements yield a binomial outcome: flow is either present or absent. Doppler indications of blood flow depend only on pulsatile properties, and high frequency but low amplitude pulses may be missed with Doppler techniques. Therefore, Doppler tends to yield a high number of false negatives, with a negligible chance of a false positive. These facts inherently make a tourniquet's performance, when it has been evaluated by Doppler alone, appear better than it otherwise would. The clinical correlation of a Doppler no-flow call is not easily defined; however, a Doppler no-flow call should indicate a significant decrease in blood flow. In those cases when Doppler is positive, the amount of blood flow may not be clinically relevant. However, as the objective of any tourniquet is to stop blood flow distal to the point of application, it is appropriate to view positive Doppler calls in a negative light.

The accuracy of Doppler measures depends on both the operator and the equipment, so it allows for both interoperator and interequipment variability. This study tried to mitigate these factors by limiting the number of operators, providing adequate and uniform operator training, using the same Doppler stethoscope, acquiring a Doppler signal and marking those Doppler measurement sites before the tourniquets were applied.

In general, all tourniquets performed worse on lower than on upper extremities, a result likely due to several factors including deeper artery supply and thicker musculature surrounding lower extremity arteries. These factors increase the pressure necessary for occlusion.

Upper Extremities

The Doppler data for upper extremity trials are presented in Table 6. According to these results, the TIAX had Doppler no-flow calls for 100% of the trials in which no mechanical failure occurred. This result indicates that the TIAX performs well on upper extremities when it does not fail mechanically. However, the overall failure rate of the TIAX is unacceptable. No statistically significant difference appears among the tourniquets, with the exceptions of the McMillan and the NATO, both of which performed worse than the majority of all others tested. Although why they performed worse is unclear, it is interesting to note that both of these are windlass systems.

Lower Extremities

The Doppler data for lower extremity trials are presented in Table 7. According to this data, the CAT performed better than all other tourniquets, with its no-flow call rate of 73.9%. Statistically, there was no difference among all tourniquets, except for the NATO and the OHT-2: the OHT-2, with a 0% Doppler no-flow rate, performed worse than the NATO. This is believed to result from the OHT-2's tightening mechanism, which allows the tourniquet to be tightened initially but which has no secondary tightening mechanism to give the user an added mechanical advantage. This lack of mechanical advantage is significant in lower extremities and is likely due to the increased tissue mass that must be compressed there.

IMPEDANCE PLETHYSMOGRAPHY

As with Doppler, IPG indirectly measures blood flow. On one hand, IPG is valuable because its data yields parametric results and allows a somewhat precise interpretation of blood flow data. On the other hand, this wide range produces a high degree of variability in the data collected. This variability is evidenced by the large standard deviations recorded in this study. IPG also requires a high level of technical expertise: it requires many steps, in which there is a potential for human or mechanical problems.

Data from a total of 584 trials were included in the IPG analyses. Figures 6 and 7 illustrate the mean percentages of arterial occlusion that IPG indicates were achieved in the upper and lower extremities. In light of the highly asymmetric distribution of IPG values, a better overall indicator of efficacy than mean percentages of occlusion may be that of median percentage occlusion. However, to make inferential analyses, the mean percentage of occlusion was used.

IPG blood flow was *increased* after tourniquet application in 148 trials. The percentage of increased trials (25%) is similar to previous NEDU tourniquet study (24%).[10] Increased flow has been reported in studies of compression bandages at application pressures below systemic diastolic pressure.[28] This report suggests that our findings may be associated with occlusion pressures lower than diastolic. Increased blood flow associated with incomplete tourniquet application may have important ramifications on the battlefield: improper tourniquet application may actually increase blood loss; however, the clinical significance of this finding cannot be established without further research. The measured magnitudes of some increased flow percentages were questionable, especially the possibility of such large increases in flow. This phenomenon is beyond the scope of this study and is a topic for future research. The large magnitude of flow increase detected by IPG greatly skewed the mean results for some tourniquets and may result in inappropriately low performance estimates.

Upper Extremities

The TK-3 performed best in this category, with a mean occlusion of 70.58% and a median occlusion of 80.93%. Also performing well was the MAT, with a mean occlusion of 65.22% and a median occlusion of 85.56%. With the exception of the NATO and McMillan, the efficacies of the tourniquets' upper extremity occlusions were statistically indistinguishable. The NATO and the McMillan tourniquets performed significantly worse than other tested tourniquets: their respective mean occlusions of –16.88 and –21.41 correspond to overall increased blood flow. Median occlusions for the two tourniquets were –5.25% and 12.17%, respectively. It is unclear why the NATO and McMillan tourniquets performed worse than the others. Because raw IPG values have not been definitively correlated to blood flow, no estimation of their efficacy can be made.

Lower Extremities

The CAT performed the best in this performance measure, with a mean occlusion of 61.08% and a median occlusion of 70.49%. Also performing well was the MAT, with a mean occlusion of 57.67% and a median occlusion of 72.55%. The tourniquets' efficacies in lower extremity occlusions were statistically indistinguishable, except for those of the McMillan, NATO, and OHT-2. These three tourniquets performed significantly worse than some of the others tested: they showed mean percentage occlusions of 0.10, –6.10, and –18.60 respectively.

SUBJECTIVE RATINGS

Special Operations corpsmen have identified *arterial occlusion*, *quick application*, *light weight*, and *compact design* as the top four requirements for a combat-deployable, self-applied tourniquet.[4] Table 2 lists the physical dimensions and weights of the tourniquets evaluated in this report. It should be noted that weights are more precise than stowage volumes, since such volumes depend on stowage configurations. The TK-3 and TK-4 are the lightest tourniquets, with weights of 42.3 and 53.1 grams respectively. The TK-3 also occupies the smallest stowage volume at 113.5 cm^3. The Q tourniquet, the heaviest, occupies the most stowage volume at 328.7 grams and 681 cm^3. While not directly included in our overall rankings, these weight and volume differences are critical in product evaluation. Following tourniquet applications, subjects dictated comments critiquing each tourniquet. Those comments are included in Appendix E.

With the exception of the CAT, all of the windlass systems rated lower than the ratcheting tourniquets. This is felt overall to be due to the inherent difficulty that subjects had in securing the devices after application, especially in making one-handed applications.

Responses to the MAT were overwhelmingly positive: it received the highest ranking on the subjective scores. Users applauded such characteristics as its quickness of application and ease of use, and the sense they had of its adequate tightness after the tourniquet was secured. A minority of the users expressed slight difficulty with its plastic clip coming unhooked during its initial cinching down, but overall this was not felt to be a significant problem. With the exception of the TK-3 and TK-4, the MAT performed better, statistically, than all other tourniquets in the subjective rankings category.

The Burke, TK-3, and TK-4 also received positive responses in their subjective rankings of second, third, and fourth best, respectively. Positive aspects of the Burke were that its concept of use was easy to understand, and its application was fairly easy and quick. Problems identified with it were that its initial cinching down was extremely difficult to perform with one hand, and ratcheting the device was difficult because its plastic teeth slipped once the tourniquet was under tension. Because of the teeth slipping, many subjects felt that they were unable to get the tourniquet as tight as they would have liked.

Subjects liked the simple design and easy application of the both the TK-3 and TK-4, and they felt that these tourniquets worked well and achieved overall adequate tightness, especially for upper extremity applications. Some expressed concerns about the slippery tourniquet fabric and their difficulty in securing the hooks, especially with one-handed applications. A significant number of test subjects had doubts about the TK-3's occlusion efficacy for lower extremity applications.

The CAT was touted as one of the better windlass tourniquets, with many overall positive subject comments. However, among the problems identified were a difficulty

with the Velcro interfering with initial applications, and a difficulty in securing the windlass after the CAT had been applied. Both of these problems were increasingly prevalent with one-handed applications.

Subjects thought that the TIAX was easily applied and achieved adequate tightness — when it did not have a mechanical failure. Another problem identified was the many revolutions of the crank required to tighten the tourniquet.

The Q tourniquet received fair ratings from test subjects, who voiced positives about its easy application and adequate tightness. Negative aspects mentioned included its bulkiness and its difficulty with initial cinching, especially during one-handed applications.

The MET also received fair ratings; however, many subjects complained of difficulty in tightening the tourniquet and in securing the windlass after application. These difficulties were increasingly prevalent with one-handed applications.

The OHT-2 was felt to be a simple tourniquet to use; however, the majority of test subjects felt as if they were unable to get the tourniquet as tight as they needed.

Subjects complained that the McMillan gave them difficulty tightening and securing it. Several subjects stated they had to loosen it to be able to secure it, and many stated that they were unable to get it tight enough.

The SOFT-T, FST, and NATO were subjectively rated to be worse than the majority; the NATO was rated as the worst overall. Subjects applauded the SOFT-T for its easy application and simple conceptual design, but they disliked the difficulty they had in securing it and in tightening it adequately enough. These complaints, as were those directed toward the majority of the windlass tourniquets, predominantly concerned one-handed applications.

The FST was disliked for its difficulty in tightening and securing. In addition, many subjects felt that the windlass was slippery and had too many sharp edges. These last two complaints likely concern difficulties that subjects had in tightening the tourniquet.

In the subject ratings categories, the NATO performed significantly worse than all other tourniquets tested. In addition to difficulty tightening and securing the NATO, subjects found it to be awkward and complicated to apply. They also felt that they were unable to achieve adequate tightness with it. All of these problems were increasingly prevalent with one-handed applications.

CUMULATIVE RANKINGS

GENERAL

Since the number of tourniquets tested was so large, a ranking method to make the data understandable was developed. This ranking method is an artificial construct to be used purely as a comparison tool for the tourniquets tested in this work. What correlation, if any, this construct may have with clinical efficacy of an individual tourniquet is uncertain. In this construct, tourniquets are placed into one of three groups, depending on the aforementioned parameters against which tourniquets are measured. Based on the pair-wise p-values from inferential analyses, the groups are subdivided as follows:

(1) Group I — Tourniquets in this group statistically performed as well as, if not better than, all other tourniquets tested.
(2) Group II — Tourniquets in this group statistically performed worse than at least one, but not more than four, other tourniquet(s).
(3) Group III — Tourniquets in this group statistically performed worse than five or more other tourniquets.

Tourniquets within a group get no credit for performing better than other tourniquets within that group. Also, no discontinuity between descriptive statistical rankings and group designation is permitted. Tables 10–17 show group designations for each of the eight tourniquet characteristics evaluated.

MECHANICAL AND APPLICATION FAILURES

Table 10.
Group Assignments Based on Tourniquet Failure Rate

Tourniquet	Failure Rate %	Group
FST	2	I
MET	2	I
TK-4	2	I
CAT	4	I
MAT	4	I
OHT-2	4	I
Q	4	I
Burke	6	I
NATO	6	I
SOFT-T	6	I
McMill	8	I
TK-3	8	I
TIAX	28	III

APPLICATION TIMES

Table 11.
Group Assignments Based on Upper Extremity Application Times

Tourniquet	Mean application time (sec)	Group
OHT-2	57.6	I
Burke	59.9	I
MAT	60.7	I
TK-3	70.4	I
Q	72.3	I
TK-4	72.8	I
TIAX	83.9	I
FST	95.1	I
CAT	97.1	I
MET	100.9	II
SOFT-T	129.6	III
NATO	138.9	III
McMill	161.4	III

Table 12.
Group Assignments Based on Lower Extremity Application Times

Tourniquet	Mean application time (sec)	Group
OHT-2	41.8	I
MAT	46.6	I
Burke	48.8	I
Q	53.7	I
MET	54.1	I
TK-3	54.2	I
SOFT-T	56.3	I
CAT	57.9	I
FST	60.7	I
TK-4	65.3	I
NATO	71.4	II
TIAX	75.0	II
McMill	89.9	III

DOPPLER FLOW MEASUREMENTS

Table 13.
Group Assignments Based on Upper Extremity Doppler Data

Tourniquet	% No-flow	Group
TIAX	100.00	I
CAT	92.00	I
MAT	92.00	I
Burke	91.67	I
TK-3	87.50	I
MET	84.00	I
TK-4	80.00	I
FST	72.00	I
Q	69.57	I
SOFT-T	68.18	I
OHT-2	58.33	I
McMill	27.27	III
NATO	21.74	III

Table 14.
Group Assignments Based on Lower Extremity Doppler Data

Tourniquet	% No-flow	Group
CAT	73.91	I
Burke	69.57	I
MAT	69.57	I
TIAX	65.00	I
Q	56.00	I
TK-4	54.17	I
TK-3	50.00	I
SOFT-T	48.00	I
MET	33.33	I
FST	25.00	I
McMill	25.00	I
NATO	8.33	II
OHT-2	0.00	III

IMPEDANCE PLETHYSMOGRAPHY

Table 15.
Group Assignments Based on Upper Extremity IPG Data

Tourniquet	Mean % Occlusion	Group
TK-3	70.58	I
MAT	65.22	I
TIAX	63.82	I
CAT	60.95	I
TK-4	59.54	I
FST	58.05	I
MET	57.83	I
Burke	46.58	I
Q	36.77	I
OHT-2	36.26	I
SOFT-T	33.74	I
NATO	–16.88	III
McMill	–21.41	III

Table 16.
Group Assignments Based on Lower Extremity IPG Data

Tourniquet	Mean % Occlusion	Group
CAT	61.08	I
MAT	57.67	I
Q	48.69	I
TK-3	36.95	I
TIAX	32.48	I
SOFT-T	32.45	I
TK-4	29.53	I
Burke	28.04	I
MET	28.02	I
FST	6.45	I
McMill	0.10	II
NATO	–6.10	II
OHT-2	–18.60	II

SUBJECTIVE RATINGS

Table 17.
Group Assignments Based on Subjective Rankings

Tourniquet	Total Score	Group
MAT	289	I
Burke	229	I
TK-3	225	I
TK-4	210	I
CAT	208	II
TIAX	198	II
Q	196	II
MET	172	II
OHT	133	II
McMill	125	II
SOFT-T	122	III
FST	114	III
NATO	54	III

OVERALL RANKINGS

Based on the group assignments from Tables 10–17, another system was created to further interpret the data gathered from this study. Tourniquets were assigned points based on group assignment for all eight parameters in which they were evaluated. The point scale is as follows:

Group I = 3 points
Group II = 2 points
Group III = 1 point

Tourniquets were further subdivided into final groups based on the following rules:

(1) Group A — received Group I assignments for all parameters evaluated.

(2) Group B — received at least one Group II assignment, but received no Group III assignments.

(3) Group C — received at least one Group III assignment.

These final rankings are provided in Table 18.

Again it must be emphasized that this ranking is an artificial construct, one designed purely to assist with interpreting the data for the thirteen tourniquets tested. It is unsure what relation, if any, this ranking has to the clinical efficacy of any particular tourniquet. Within this construct, all parameters are weighted equally. In addition, any tourniquet within a group receives no extra credit for being better than the others within that same group.

As Table 18 demonstrates, by all parameters measured, the MAT, Burke, TK-3, and TK-4 performed similarly well. These tourniquets performed better than all others tested.

It is interesting to note that by excluding the subjective rankings data, several tourniquets would have been assigned different groupings: the CAT would move from Group B to Group A, and the FST would move from Group C to Group A.

Table 18.
Total Points Ranking Based on Group Assignments

Tourniquet	Group I	Group II	Group III	Total Points	Final Group
Burke	8	0	0	24	A
MAT	8	0	0	24	A
TK-3	8	0	0	24	A
TK-4	8	0	0	24	A
CAT	7	1	0	23	B
Q	7	1	0	23	B
MET	6	2	0	22	B
FST	7	0	1	22	C
SOFT-T	6	0	2	20	C
TIAX	5	2	1	20	C
OHT-2	5	2	1	20	C
McMill	2	2	4	14	C
NATO	1	3	4	13	C

CONCLUSIONS

Using 25 test subjects, 13 tourniquets were evaluated — a total of 650 trials (50 trials per tourniquet). Tourniquets tested were the Burke, the CAT, the FST, the MAT, the McMillan, the MET, the NATO, the OHT-2, the Q, the SOFT-T, the TIAX, the TK-3, and the TK-4. Tourniquets were evaluated according to eight parameters: failure rate, application times on upper extremities, application times on lower extremities, Doppler no-flow calls for upper extremities, Doppler no-flow calls for lower extremities, IPG percent occlusion for upper extremities, IPG percent occlusion for lower extremities, and subjective ratings by test subjects.

For failure rates, the FST, MET, and TK-4 perform the best — at an overall low failure rate of 2%. However, with the exception of the TIAX, there is no statistical difference between these and any of the other tourniquets. The TIAX has an unacceptably high mechanical failure rate of 28%.

Ratcheting and stretch-retention tourniquet systems are generally applied more quickly than windlass-type tourniquets. The OHT-2 has the lowest mean application times for both upper and lower extremities; however, this is not statistically different from the majority of other tourniquets. For upper extremity application times, the SOFT-T, NATO, and McMillan perform significantly worse than the majority of other tourniquets. For lower extremity application times, the McMillan performs significantly worse than the majority of other tourniquets. It is likely that the variance and overall mean of application times would be improved with additional tourniquet-specific training.

Doppler and IPG are two indirect modalities of measurement for occlusion efficacy. As such, a definitive determination of occlusion efficacy can be made only through direct measurement of arterial blood flow.

As for the Doppler data, all tourniquets perform better on upper extremities than on lower extremities. For upper extremity applications, the TIAX has the highest percentage of Doppler no-flow calls of 100%. However, the TIAX has an unacceptably high failure rate. The McMillan and NATO tourniquets perform worse than the majority of other tourniquets for upper extremity applications. For lower extremity applications, the CAT has a higher percentage of Doppler no-flow calls (73.9%) than all other tourniquets. However, this is not statistically different from the majority of other tourniquets. The OHT-2, with a Doppler no-flow call percentage of 0%, performs statistically worse than many other tourniquets.

In light of the highly asymmetric distribution of IPG values, a better overall indicator of efficacy may be median percentage occlusion. However, when inferential analyses were made, the mean percentage occlusion was used. When evaluated by IPG, the TK-3 had the highest mean occlusion percentages for upper extremity applications, with a mean occlusion of 70.58% and a median occlusion of 80.93%. The MAT also performed well on upper extremities, with a mean occlusion of 65.22% and a median occlusion of 85.56%. Neither the TK-3 nor the MAT were statistically distinguishable

from the majority of other tourniquets. The NATO and the McMillan tourniquets performed worse than all other tourniquets tested.

For lower extremity occlusion efficacy as measured by IPG, the CAT performed best, with a mean occlusion of 61.08% and a median occlusion of 70.49%. Also performing well was the MAT, with a mean occlusion of 57.67% and a median occlusion of 72.55%. However, the CAT and MAT were not statistically different from the majority of other tourniquets. The McMillan, NATO, and OHT-2 performed significantly worse than some of the other tourniquets tested.

For subjective ratings, the MAT had the highest overall subjective scores. With the exception of the TK-3 and TK-4, the MAT performed statistically better than all other tourniquets tested. The SOFT-T, FST, and NATO were rated worse than all other tourniquets in the subjective ratings category.

Using the artificial construct designed for this study and weighing all eight parameters measured equally, the Burke, MAT, TK-3, and TK-4 performed equally with scores of 24 out of 24 points possible. If the subjective data were excluded, the CAT and the FST would also move into this grouping.

RECOMMENDATIONS

From the data obtained and analyzed in this study, we recommend that one of the tourniquets which achieved a Group A rating (statistically equal to or better than all other tourniquets in every parameter tested) be highly favored in selection for forward deployment. The selection of relevant criteria to be used in determining final group assignment for overall ratings of the tourniquets depends on the priorities that the sponsor may wish to assign to the criteria.

Other characteristics of the tourniquets — characteristics such as weight, stowage volume, cost, and ease of manufacturing — that constitute significantly important differences to the sponsor should be considered in addition to the factors included in this analysis.

Familiarization training should accompany deployment of any self-applied tourniquet, because simple perusal of the instructions provided by the manufacturer is insufficient to ensure proper application when the need arises.

Additional research is recommended for increases in blood flow detected by IPG, increases that may occur with inadequate tourniquet application. To ascertain the reality of this phenomenon, such research would likely need to combine and correlate direct measurements of arterial blood flow with indirect methods. Future tourniquet evaluations should be based on available measurement methodologies that provide a more direct correlation to clinical effectiveness.

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APPENDIX A

PLANNED TEST MATRIX

Subject	1		2		3		4		5		6		7	
Day	U	L	U	L	U	L	U	L	U	L	U	L	U	L
1	Burke	FST	MET	TIAX	CAT	McMill	FST	CAT	TK-3	NATO	MAT	OHT-2	MAT	TIAX
2	McMill	Burke	NATO	SOFT-T	TK-3	MAT	TIAX	MAT	TIAX	CAT	Q	CAT	TK-4	MET
3	MAT	McMill	Q	OHT-2	TIAX	TK-4	McMill	TIAX	MET	TK-3	SOFT-T	FST	SOFT-T	OHT-2
4	OHT-2	MET	TK-3	CAT	TK-4	Q	OHT-2	SOFT-T	SOFT-T	MAT	Burke	TIAX	FST	NATO
5	CAT	NATO	TIAX	TK-3	FST	TK-3	Q	NATO	Burke	Q	McMill	MET	TIAX	McMill
6	TK-4	MAT	SOFT-T	TK-4	MET	SOFT-T	TK-3	McMill	OHT-2	TIAX	OHT-2	NATO	NATO	Q
7	FST	Q	FST	Q	NATO	Burke	MAT	MET	CAT	SOFT-T	NATO	Burke	McMill	TK-3
8	SOFT-T	TK-4	TK-4	MAT	OHT-2	NATO	CAT	Burke	Q	MET	MET	SOFT-T	CAT	FST
9	TIAX	TK-3	CAT	NATO	McMill	MET	MET	TK-4	MAT	Burke	FST	TK-3	OHT-2	TK-4
10	TK-3	CAT	OHT-2	MET	Burke	TIAX	Burke	TK-3	McMill	FST	TK-4	Q	MET	MAT
11	Q	OHT-2	MAT	McMill	SOFT-T	FST	NATO	FST	NATO	TK-4	TIAX	TK-4	Burke	CAT
12	NATO	SOFT-T	McMill	Burke	Q	CAT	SOFT-T	Q	FST	OHT-2	TK-3	MAT	TK-3	Burke
13	MET	TIAX	Burke	FST	MAT	OHT-2	TK-4	OHT-2	TK-4	McMill	CAT	McMill	Q	SOFT-T
Subject	8		9		10		11		12		13		14	
Day	U	L	U	L	U	L	U	L	U	L	U	L	U	L
1	SOFT-T	Q	Q	SOFT-T	MET	TK-4	Burke	TK-3	OHT-2	Burke	NATO	FST	FST	CAT
2	NATO	FST	TK-3	Burke	OHT-2	SOFT-T	MET	TK-4	Q	McMill	McMill	TIAX	Burke	TK-3
3	CAT	Burke	Burke	CAT	Q	NATO	MAT	MET	FST	MAT	TK-3	McMill	McMill	TIAX
4	McMill	TIAX	MET	MAT	CAT	Burke	Q	NATO	TK-3	OHT-2	TK-4	OHT-2	MET	TK-4
5	OHT-2	SOFT-T	OHT-2	TK-4	MAT	MET	FST	CAT	TK-4	CAT	SOFT-T	Q	NATO	FST
6	TK-3	McMill	CAT	FST	FST	CAT	TIAX	MAT	Burke	TK-4	Burke	TK-3	MAT	MET
7	TK-4	OHT-2	McMill	TK-3	TIAX	MAT	TK-4	OHT-2	MET	FST	TIAX	MAT	Q	NATO
8	TIAX	MAT	NATO	Q	Burke	TK-3	TK-3	McMill	McMill	SOFT-T	FST	CAT	TK-4	OHT-2
9	FST	CAT	TIAX	McMill	SOFT-T	Q	OHT-2	SOFT-T	NATO	TIAX	MAT	MET	TK-3	McMill
10	Q	NATO	FST	NATO	TK-4	OHT-2	McMill	TIAX	SOFT-T	TK-3	CAT	Burke	CAT	Burke
11	MAT	MET	SOFT-T	OHT-2	TK-3	McMill	CAT	Burke	TIAX	Q	Q	NATO	OHT-2	SOFT-T
12	MET	TK-4	TK-4	MET	McMill	TIAX	NATO	FST	MAT	NATO	OHT-2	SOFT-T	SOFT-T	Q
13	Burke	TK-3	MAT	TIAX	NATO	FST	SOFT-T	Q	CAT	MET	MET	TK-4	TIAX	MAT

(U)=upper extremity
(L)=lower extremity

Subject	15		16		17		18		19		20		21	
Day	U	L	U	L	U	L	U	L	U	L	U	L	U	L
1	McMill	TK-3	TIAX	MAT	NATO	MAT	OHT-2	TK-4	TIAX	SOFT-T	TK-3	NATO	TK-4	McMillI
2	MAT	TIAX	SOFT-T	Q	CAT	TK-4	CAT	FST	MET	NATO	TK-4	McMillI	FST	OHT-2
3	TK-4	MET	OHT-2	SOFT-T	TK-3	SOFT-T	FST	NATO	OHT-2	CAT	MET	TK-3	NATO	TK-4
4	Q	SOFT-T	CAT	Burke	MAT	FST	TIAX	McMillI	NATO	McMillI	NATO	TK-4	McMillI	FST
5	TK-3	Burke	TK-3	McMillI	Q	TIAX	MET	MAT	McMillI	OHT-2	CAT	SOFT-T	MAT	Burke
6	SOFT-T	OHT-2	TK-4	OHT-2	TIAX	NATO	NATO	Q	Q	TK-3	MAT	Burke	Q	MET
7	Burke	CAT	Q	NATO	SOFT-T	McMillI	Burke	CAT	TK-3	TK-4	OHT-2	TIAX	CAT	SOFT-T
8	NATO	Q	MAT	MET	MET	CAT	SOFT-T	OHT-2	FST	TIAX	McMillI	FST	OHT-2	TIAX
9	MET	MAT	NATO	FST	Burke	OHT-2	TK-3	Burke	TK-4	FST	SOFT-T	MAT	Burke	Q
10	TIAX	McMillI	MET	TK-4	FST	MET	Q	SOFT-T	MAT	Q	TIAX	CAT	SOFT-T	MAT
11	FST	NATO	McMillI	TIAX	TK-4	Burke	TK-4	MET	CAT	MAT	Burke	Q	MET	TK-3
12	CAT	FST	Burke	TK-3	OHT-2	TK-3	MAT	TIAX	Burke	MET	FST	OHT-2	TIAX	CAT
13	OHT-2	TK-4	FST	CAT	McMillI	Q	McMillI	TK-3	SOFT-T	Burke	Q	MET	TK-3	NATO

Subject	22		23		24		25		26	
Day	U	L	U	L	U	L	U	L	U	L
1	TK-4	OHT-2	CAT	MET	McMillI	Q	SOFT-T	Burke	Q	MET
2	SOFT-T	Q	MAT	NATO	OHT-2	TK-3	Burke	MET	FST	OHT-2
3	NATO	FST	TIAX	Q	TK-4	Burke	CAT	MAT	Burke	Q
4	Burke	TK-3	SOFT-T	TK-3	FST	MET	MAT	Q	TIAX	CAT
5	MET	TK-4	NATO	TIAX	Burke	OHT-2	TK-4	FST	SOFT-T	MAT
6	CAT	Burke	McMillI	SOFT-T	MET	CAT	FST	TIAX	McMillI	FST
7	MAT	MET	MET	FST	SOFT-T	McMillI	TK-3	TK-4	OHT-2	TIAX
8	TK-3	McMillI	Burke	TK-4	TIAX	NATO	Q	TK-3	MAT	Burke
9	Q	NATO	TK-4	CAT	Q	TIAX	McMillI	OHT-2	CAT	SOFT-T
10	OHT-2	SOFT-T	TK-3	OHT-2	MAT	FST	NATO	McMillI	NATO	TK-4
11	McMillI	TIAX	FST	MAT	TK-3	SOFT-T	OHT-2	CAT	MET	TK-3
12	TIAX	MAT	Q	McMillI	CAT	TK-4	MET	NATO	TK-4	McMillI
13	FST	CAT	OHT-2	Burke	NATO	MAT	TIAX	SOFT-T	TK-3	NATO

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APPENDIX B

IMPEDANCE PLETHYSMOGRAPHY DATA ANALYSIS

As presented by the WinDaq Waveform Browser, an example of the five traces recorded during an upper extremity tourniquet trial is shown in Figure B-1: forearm base electrical resistance (Ro) and event marks, electrocardiogram (ECG), forearm electrical resistance changes (ΔR), first derivative of forearm electrical resistance changes (dR/dT), and forearm Doppler blood flow velocity.

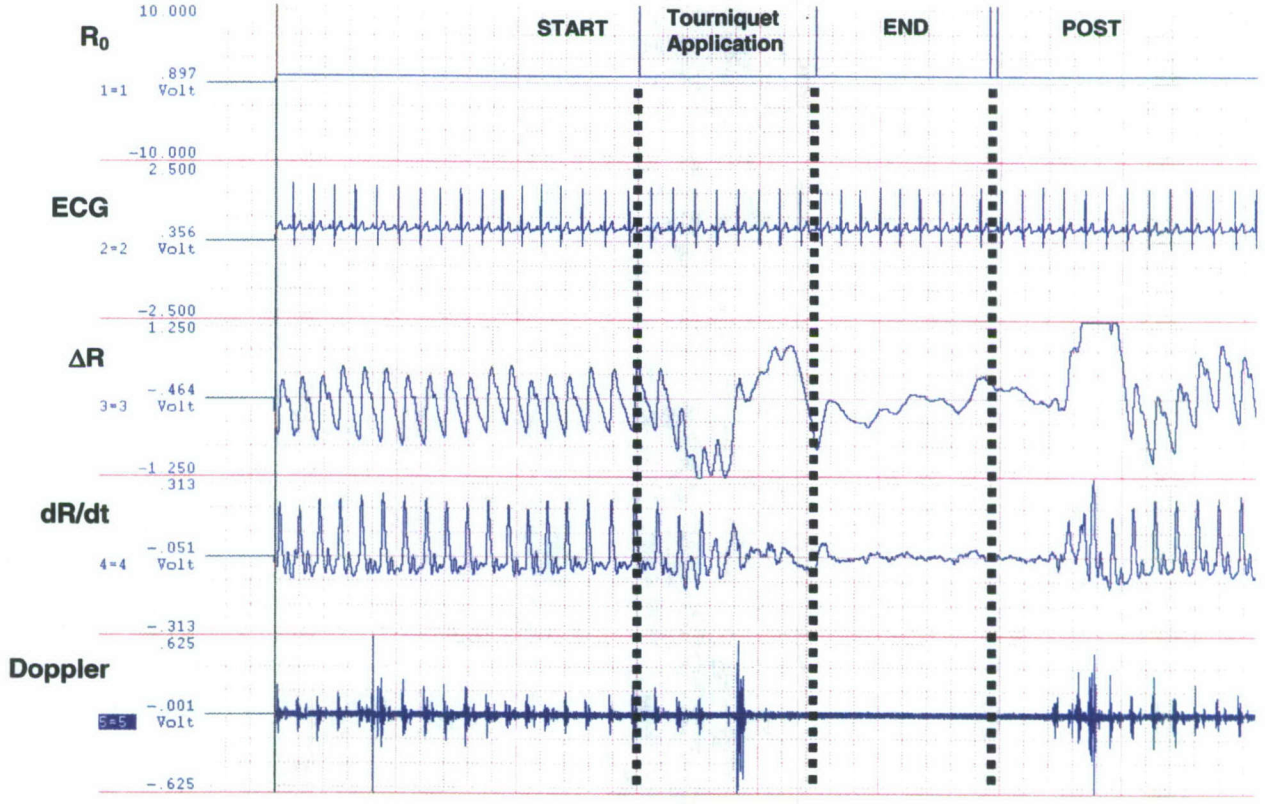

Figure B-1. The five impedance plethysmographic data traces from a tourniquet trial completed under ideal laboratory conditions. From top to bottom: Ro and event marks, ECG, ΔR, dR/dT, and Doppler blood flow velocity. Progress through the trial sequence is denoted by the event marks in the top trace. Dotted vertical lines overlay the figure to extend event marks in the top trace through all traces. A baseline period was established between the start of the recording period and the first single event mark in the top trace. The tourniquet was then applied and tightened in the subsequent period between the two single event marks. The tourniquet remained tight between the right single event mark and the following double event mark. The tourniquet was released after the double event marks.

This trial was completed under ideal laboratory conditions with the subject lying quietly in a supine position while the tourniquet was applied and tightened by a technician until total disappearance of the wrist Doppler auditory sounds. Selected subsegments of the

labeled START, END, and POST segments of this run, analogous to segments of the same names described in the Methods/Procedures section in this report, are illustrated in Figures B-2 through B-4.

Figure B-2. Selected START sequence from Figure B-1. Note the fully developed blood flow waveforms (Trace 3) and the corresponding Doppler signals for each cardiac cycle (Trace 5).

Figure B-3. Selected END sequence from Figure B-1. Note the absence of a Doppler waveform (Trace 5) and the remaining, but markedly attenuated, impedance ΔR waveform (Trace 3).

Figure B-4. Selected POST sequence from Figure B-1. Note that the amplitudes of the impedance ΔR pulse waveforms (Trace 3) are increased from those in the START period due to reactive hyperemia after tourniquet release and that the Doppler signals (Trace 5) are reestablished.

Quantitative measures of monitored segment blood flow and hemodynamic status were computed retroactively from the START, END, and POST segments of each tourniquet trial suitable for analysis with a custom program, Rheoencephalographic Impedance Scanning System (RheoSys), developed by LDM Associates. The analysis proceeds from a graphical display of the overall impedance ΔR and ECG traces. The operator first selects individual impedance pulse waveforms from which blood flow and other hemodynamic parameters are to be computed. RheoSys then proposes the placement of seven vertical reference lines in each selected pulse waveform, as illustrated for one selected pulse in Figure B-5. The seven lines mark the following features of the selected pulse waveform:

1. Peak of the ECG QRS complex immediately preceding the selected IPG pulse,
2. Start of the systolic upslope of the IPG pulse,
3. Maximum amplitude of the IPG pulse,
4. Position of the dicrotic notch in the IPG pulse,
5. Maximum amplitude of the postdicrotic segment of the IPG pulse,
6. Peak of the ECG QRS complex immediately after the systolic upslope of the selected IPG pulse, and
7. Start of the systolic upslope of the next IPG pulse.

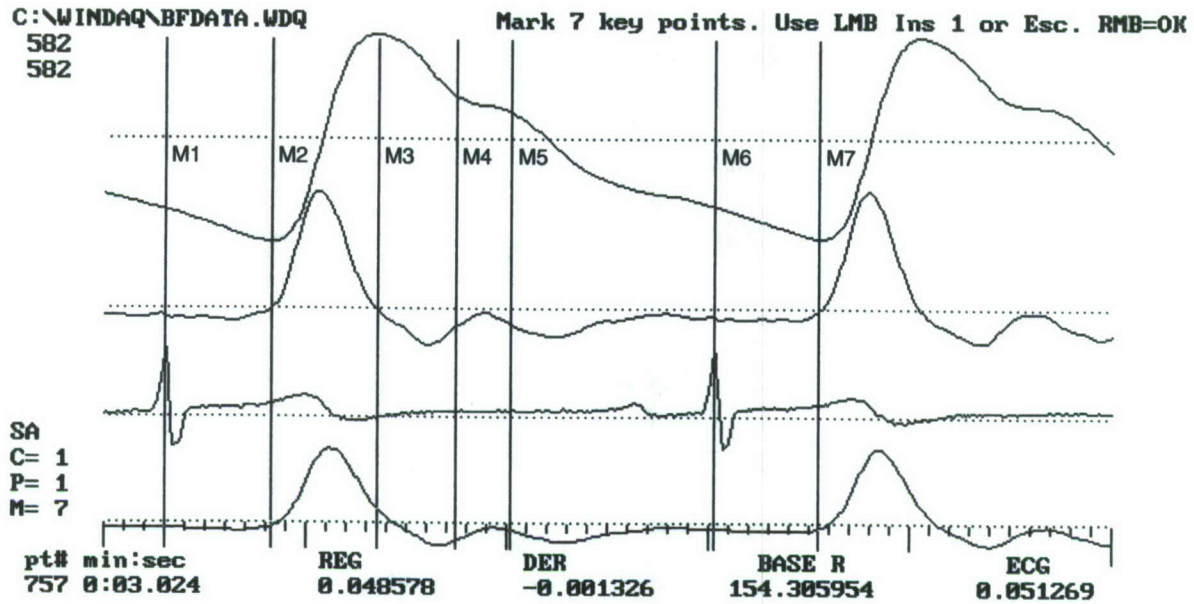

Figure B-5. Landmarks in an impedance pulse, marked by vertical lines labeled M1, M2,...,M7. Traces from top to bottom: IPG ΔR waveform, calculated first derivative of the ΔR waveform (dR/dt) in the top trace, ECG waveform, and dR/dt waveform provided directly by the THRIM hardware. (Only the dR/dt waveform computed from the IPG ΔR waveform is used in RheoSys.) The horizontal dotted line in the computed dR/dt trace is the dR/dt = 0 line. The time at each landmark is t_{M1}, t_{M2}, ..., and t_{M7}, respectively, and the corresponding IPG ΔR amplitude is R_{M1}, R_{M2}, ..., and R_{M7}, respectively.

After the operator either accepts or adjusts the placement of these reference lines, the times and IPG ΔR signal amplitudes at the lines are used to calculate the following cardiovascular and hemodynamic parameters for each pulse:

HR (beats/min) Heart rate $= 60/(t_{M6} - t_{M1})$, (B1)
with t_{M1} and t_{M6} in seconds.

A (Ohm) Rheographic index of maximum systolic pulse amplitude given by

$$A = R_{M3} - \frac{(t_{M3} - t_{M2}) \cdot (R_{M7} - R_{M2})}{(t_{M7} - t_{M2})} \quad \text{(B2)}$$

ST (Ohm-seconds) Total area under the selected IPG pulse waveform from the start of the pulse at t_{M2} to the start of the next pulse at t_{M7}:

$$ST = \sum_{i=j}^{k} R_i \Big/ Sr - 0.5 \cdot (R_{M7} - R_{M2})(t_{M7} - t_{M2}) \quad \text{(B3)}$$

where j is the index for the IPG resistance datum at t_{M2}, k is the corresponding index at t_{M7}, and Sr is the sample rate (s^{-1}).

R_0 (Ohm)

Average base resistance of the monitored segment during the IPG pulse given by

$$R_0 = 0.5 \cdot (R_{M2} + R_{M7}). \quad \text{(B4)}$$

EXHT (Ohm)

Extrapolated IPG pulse amplitude given by Nyboer (1970) back-projection:

$$EXHT = (R_{M4} - R_{M2}) + (t_{M4} - t_{M2})(R_{M3} - R_{M4})/(t_{M4} - t_{M3}) \quad \text{(B5)}$$

BFA (ml/min)

Absolute segmental blood flow given by

$$BFA = HR \cdot EXHT \cdot \rho \cdot L^2 / R_0^2, \quad \text{(B6)}$$

where ρ is the specific resistivity of blood [150 Ohm-cm (Mohapatra, 1981)] and L (cm) is the separation distance between the two segmental sensing electrodes.

BF (ml/min·ml)

Normalized segmental blood flow given by

$$BF = BFA / Vg, \quad \text{(B7)}$$

where $Vg = C^2 L / 4\pi$ is the segmental geometric volume with C (cm) as the measured maximum circumference of the monitored segment.

PTT (s)

$$\text{Pulse transit time} = (t_{M2} - t_{M1}), \quad \text{(B8)}$$

in relation to the time interval between the ECG QRS complex immediately preceding the selected IPG pulse and the start of the selected IPG pulse (Nitzan et al., 2002).

TIN (s)

$$\text{Time of excess arterial inflow} = (t_{M4} - t_{M1}), \quad \text{(B9)}$$

the time period from start of the IPG pulse until the occurrence of the dicrotic notch (Wu, 1992).

TOUT (s)

$$\text{Time of excess venous outflow} = (t_{M7} - t_{M4}), \quad \text{(B10)}$$

the time period from the dicrotic notch until the end of the IPG pulse (Wu, 1992).

Note that A, ST, and EXHT are measures of pulse morphology independent of heart rate. In contrast, BF includes the influence of heart rate, which was found to be substantially increased during the occlusion (END) period in some trials.

The calculated output parameter values from *RheoSys* were stored in Excel spreadsheet format for statistical analysis.

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APPENDIX C

DESCRIPTIONS OF FAILURES

Tourniquet	Subject	Extremity	Description
Burke	26	Upper	Pulled strap out of d-ring; unable to tighten device
Burke	19	Lower	stripped ratchet mechanism
Burke	24	Lower	bracket separated from belt
CAT	20	Lower	ripped handle out of canvass
CAT	27	Lower	handle broke the strap
FST	6	Lower	strap assembled backwards
MAT	19	Lower	plastic on plastic
MAT	25	Lower	closure mechanism broke
McMill	25	Lower	came unsecured when subject laid down
McMill	3	Upper	application failure; unable to secure windlass
McMill	15	Upper	application failure; unable to secure windlass
McMill	18	Upper	application failure; unable to secure windlass
MET	19	Lower	handle ripped strap
NATO	21	Upper	loose ring came off strap
NATO	24	Lower	loose ring came off strap
NATO	12	Upper	application failure; floating ring trapped
OHT-2	14	Upper	broke "D" ring
OHT-2	19	Lower	broke "D" ring
Q	4	Upper	ratchet strap broke
Q	9	Upper	belt caught in ratchet mechanism
SOFT-T	19	Upper	ripped handle off strap
SOFT-T	3	Upper	application failure; unable to secure windlass
SOFT-T	25	Upper	application failure; unable to secure windlass
TIAX	2	Upper	strap came off crank housing
TIAX	3	Upper	closure mechanism broke
TIAX	5	Upper	closure mechanism broke
TIAX	13	Upper	strap came off crank housing
TIAX	15	Upper	crank handle broke
TIAX	16	Upper	crank handle broke

Tourniquet	Subject	Extremity	Description
TIAX	18	Upper	crank housing broke
TIAX	23	Upper	strap came off crank housing
TIAX	27	Upper	broke plastic closure device
TIAX	1	Lower	strap came off crank housing
TIAX	3	Lower	strap came out of crank housing
TIAX	6	Lower	strap came off crank housing
TIAX	18	Lower	strap came off crank housing
TIAX	19	Lower	strap came out of crank housing
TK-3	3	Upper	securing hook rings came undone, hook separated
TK-3	4	Lower	rings off band, band ripped
TK-3	10	Lower	clips slid off
TK-3	26	Lower	hook came off elastic band
TK-4	27	Lower	nylon strap broke

APPENDIX D

P-VALUES

For all the p-values presented in this appendix, bolded values are considered statistically different ($p<0.05$).

Table D-1.
P-Value Results for Pair-Wise Comparison with T-Tests of Upper Extremity Application Times

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	0.18488	-	-	-	-	-	-	-	-	-	-	-
FST	0.28628	1	-	-	-	-	-	-	-	-	-	-
MAT	1	0.20236	0.31302	-	-	-	-	-	-	-	-	-
McMill	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	-	-	-	-	-	-	-	-
MET	0.08136	1	1	0.08918	**< 0.001**	-	-	-	-	-	-	-
NATO	**< 0.001**	0.06737	**0.04034**	**< 0.001**	1	0.15911	-	-	-	-	-	-
OHT-2	1	0.11177	0.17774	1	**< 0.001**	**0.0459**	**< 0.001**	-	-	-	-	-
Q	1	1	1	1	**< 0.001**	1	**< 0.001**	1	-	-	-	-
SOFT-T	**< 0.001**	0.49285	0.32093	**< 0.001**	0.55737	0.99566	1	**< 0.001**	**< 0.001**	-	-	-
TIAX	1	1	1	1	**< 0.001**	1	**0.01024**	1	1	0.09111	-	-
TK-3	1	1	1	1	**< 0.001**	0.71601	**< 0.001**	1	1	**< 0.001**	1	-
TK-4	1	1	1	1	**< 0.001**	1	**< 0.001**	1	1	**< 0.001**	1	1

Table D-2.
P-Value Results for Pair-Wise Comparison with T-Tests of Lower Extremity Application Times

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	1	-	-	-	-	-	-	-	-	-	-	-
FST	1	1	-	-	-	-	-	-	-	-	-	-
MAT	1	1	1	-	-	-	-	-	-	-	-	-
McMill	**<0.001**	**0.00196**	**0.00722**	**<0.001**	-	-	-	-	-	-	-	-
MET	1	1	1	1	**<0.001**	-	-	-	-	-	-	-
NATO	0.17775	1	1	0.0704	0.7619	1	-	-	-	-	-	-
OHT-2	1	1	0.68465	1	**<0.001**	1	**0.00614**	-	-	-	-	-
Q	1	1	1	1	**<0.001**	1	0.90721	1	-	-	-	-
SOFT-T	1	1	1	1	**<0.001**	1	1	1	1	-	-	-
TIAX	0.06459	1	1	**0.02444**	1	0.46975	1	**0.00198**	0.37473	0.89114	-	-
TK-3	1	1	1	1	**<0.001**	1	1	1	1	1	0.55057	-
TK-4	1	1	1	0.7619	0.06885	1	1	0.11125	1	1	1	1

Table D-3.
P-Value Results for Pair-Wise Comparison Test for Proportions of Upper Extremity Doppler No-Flow Data

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	1	-	-	-	-	-	-	-	-	-	-	-
FST	1	1	-	-	-	-	-	-	-	-	-	-
MAT	1	1	1	-	-	-	-	-	-	-	-	-
McMill	**0.00218**	**0.00155**	0.34363	**0.00155**	-	-	-	-	-	-	-	-
MET	1	1	1	1	**0.01876**	-	-	-	-	-	-	-
NATO	**< 0.001**	**< 0.001**	0.09011	**0.00027**	1	**0.00377**	-	-	-	-	-	-
OHT-2	1	0.91606	1	0.91606	1	1	1	-	-	-	-	-
Q	1	1	1	1	0.65632	1	0.19378	1	-	-	-	-
SOFT-T	1	1	1	1	0.91368	1	0.28498	1	1	-	-	-
TIAX	1	1	1	1	**0.00232**	1	**< 0.001**	0.54525	1	1	-	-
TK-3	1	1	1	1	**0.00822**	1	**0.00161**	1	1	1	1	-
TK-4	1	1	1	1	**0.05564**	1	**0.01198**	1	1	1	1	1

Table D-4.
P-Value Results for Pair-Wise Comparison Test for Proportions of Lower Extremity Doppler No-Flow Data

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	1	-	-	-	-	-	-	-	-	-	-	-
FST	0.34363	0.14097	-	-	-	-	-	-	-	-	-	-
MAT	1	1	0.34363	-	-	-	-	-	-	-	-	-
McMill	0.34363	0.14097	1	0.34363	-	-	-	-	-	-	-	-
MET	1	0.69342	1	1	1	-	-	-	-	-	-	-
NATO	**0.00425**	**0.00137**	1	**0.00425**	1	1	-	-	-	-	-	-
OHT-2	**< 0.001**	**< 0.001**	1	**< 0.001**	1	0.37555	1	-	-	-	-	-
Q	1	1	1	1	1	1	0.07558	**0.00422**	-	-	-	-
SOFT-T	1	1	1	1	1	1	0.34363	**0.02359**	1	-	-	-
TIAX	1	1	0.98258	1	0.98258	1	**0.01962**	**0.00092**	1	1	-	-
TK-3	1	1	1	1	1	1	0.30968	**0.01962**	1	1	1	-
TK-4	1	1	1	1	1	1	0.11997	**0.0068**	1	1	1	1

Table D-5.
P-Value Results for Pair-Wise Comparison with T-Tests of Upper Extremity IPG Data

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	1	-	-	-	-	-	-	-	-	-	-	-
FST	1	1	-	-	-	-	-	-	-	-	-	-
MAT	1	1	1	-	-	-	-	-	-	-	-	-
McMill	**0.00654**	**<0.001**	**<0.001**	**<0.001**	-	-	-	-	-	-	-	-
MET	1	1	1	1	**<0.001**	-	-	-	-	-	-	-
NATO	**0.02481**	**0.00153**	**0.00207**	**<0.001**	1	**0.00215**	-	-	-	-	-	-
OHT-2	1	1	1	1	0.07292	1	0.20352	-	-	-	-	-
Q	1	1	1	1	0.06709	1	0.18934	1	-	-	-	-
SOFT-T	1	1	1	1	0.13059	1	0.33766	1	1	-	-	-
TIAX	1	1	1	1	**<0.001**	1	**0.00327**	1	1	1	-	-
TK-3	1	1	1	1	**<0.001**	1	**<0.001**	1	1	1	1	-
TK-4	1	1	1	1	**<0.001**	1	**0.0015**	1	1	1	1	1

Table D-6.
P-Value Results for Pair-Wise Comparison with T-Tests of Lower Extremity IPG Data

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	1	-	-	-	-	-	-	-	-	-	-	-
FST	1	0.09696	-	-	-	-	-	-	-	-	-	-
MAT	1	1	0.17979	-	-	-	-	-	-	-	-	-
McMill	1	**0.02693**	1	0.05476	-	-	-	-	-	-	-	-
MET	1	1	1	1	1	-	-	-	-	-	-	-
NATO	1	**0.00679**	1	**0.01467**	1	1	-	-	-	-	-	-
OHT-2	0.3552	**<0.001**	1	**<0.001**	1	0.3552	1	-	-	-	-	-
Q	1	1	0.63407	1	0.21532	1	0.06608	**0.00396**	-	-	-	-
SOFT-T	1	1	1	1	1	1	1	0.15159	1	-	-	-
TIAX	1	1	1	1	1	1	1	0.2923	1	1	-	-
TK-3	1	1	1	1	1	1	0.82055	0.10508	1	1	1	-
TK-4	1	1	1	1	1	1	1	0.25407	1	1	1	1

Table D-7.
P-Value Results for Pair-Wise Comparison Using Wilcoxon Signed Rank Sum Test for Subjective Ratings Data

	Burke	CAT	FST	MAT	McMill	MET	NATO	OHT-2	Q	SOFT-T	TIAX	TK-3
CAT	1	-	-	-	-	-	-	-	-	-	-	-
FST	**<0.001**	**0.00377**	-	-	-	-	-	-	-	-	-	-
MAT	**0.03292**	**0.0014**	**<0.001**	-	-	-	-	-	-	-	-	-
McMill	**<0.001**	**0.01498**	1	**<0.001**	-	-	-	-	-	-	-	-
MET	0.18904	1	0.12127	**<0.001**	0.71989	-	-	-	-	-	-	-
NATO	**<0.001**	**<0.001**	**0.02935**	**<0.001**	**0.00508**	**<0.001**	-	-	-	-	-	-
OHT-2	**0.00393**	**0.0407**	1	**<0.001**	1	1	**0.00142**	-	-	-	-	-
Q	1	1	**0.12127**	**0.00878**	0.19584	1	**<0.001**	0.52012	-	-	-	-
SOFT-T	**<0.001**	**0.00393**	1	**<0.001**	1	0.26054	**0.0014**	1	0.17377	-	-	-
TIAX	1	1	0.18017	**0.01262**	0.18507	1	**0.00111**	0.5578	1	0.15208	-	-
TK-3	1	1	**0.00178**	0.0582	**0.00336**	0.26646	**<0.001**	**0.01129**	1	**0.00123**	1	-
TK-4	1	1	**0.02505**	0.10898	0.09009	1	**<0.001**	0.13149	1	**0.03365**	1	1

APPENDIX E

POSTAPPLICATION SUBJECT NARRATIVES

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
Burke	1	Upper	Difficult to remove slack from webbing due to sand. Although it worked well, you could feel the sand in the ratcheting mechanism. Sand did not hinder it, but it could have.
Burke	2	Upper	The device tightening the first strap is difficult to do with one hand. You have to trap the device between your leg and pull it with your hand. Tightening the device down extremely tight. I believe sand got in the device and it was difficult to release the device. I had to cut it.
Burke	4	Upper	It got to the point where I could have got it tighter, don't know if it occluded but it probably did. It worked alright.
Burke	5	Upper	Application was fairly simple. The ratcheting part to tighten the device was pretty easy until I got to the part were it was close to being as tight as I wanted it. Then it seemed like it didn't want to move to the next tooth or it was slipping. It didn't get as tight as I wanted it to. I could have gotten 2 or 3 more clicks tighter.
Burke	6	Upper	Initial adjustment was cumbersome, but the ratcheting mechanism worked well.
Burke	9	Upper	Seemed like it was hard to pull the big strap on the arm. Cranking the mechanism, once it popped, it wouldn't get any tighter. It seemed pretty tight.
Burke	10	Upper	I thought the initial getting it tight was difficult with just one arm. The latch assembly thing that gets it tight worked pretty well. It seemed to work pretty well.
Burke	11	Upper	Fairly easy to put on. I have a skinny arm, and it seemed when I first tightened it without using the ratchet, not to go on very tight so I hesitated before using the ratchet. Also the ratchet seemed to pinch my triceps. It was a bit painful even through the blouse.
Burke	12	Upper	Seemed to work real fine.
Burke	14	Upper	I thought it worked well, with the exception that it was painful. It pinched my skin, but in an emergency I don't think that would matter.
Burke	15	Upper	It was easy no problems.
Burke	16	Upper	Went on easily, tightened up easily. Felt like it was pretty secure. Didn't have any problems with it.
Burke	17	Upper	Easy to apply and cinch down. The ratcheting was simple.
Burke	19	Upper	Seemed to work pretty well. I ratcheted it on pretty good and it went on pretty easily. I thought I broke it, but it held.
Burke	20	Upper	Application was pretty easy. It was a good concept. It was able to constrict blood flow and you felt it. Only problem is if you have really skinny arms, I don't know if you would have enough notches to restrict blood flow. That's just my opinion. Other than that I liked it.
Burke	21	Upper	The strap was extremely difficult to cinch down, it took a very long time. Even when it was fully cinched down, it still left a large gap around my arm. Device was definitely designed for larger armed individuals. However after that had been completed, the ratcheting device worked very well. Definitely got adequate constriction.
Burke	22	Upper	A little complicated, but still pretty simple.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
Burke	23	Upper	Very easy to use.
Burke	25	Upper	Put it on, seemed to go on fairly easy. Slight difficulty tightening down so I could start the ratcheting. Started the ratcheting, seemed like that's all I could go, didn't seem like I could get it any tighter. Seemed like it should have been tighter, but it wasn't.
Burke	26	Upper	Inadvertently pulled the tighten strap out of the buckle and had to rethread it. When I rethreaded it, I didn't get it past a certain point where it would let it slide so it locked up. So it was a device failure. I don't know if it was me or the training, but blindfolded I pulled the wrong part.
Burke	27	Upper	Was able to get it on pretty easily. It was kind of hard to tighten down with one arm initially. I ratcheted as much as I could until it started slipping. It got to a point that I could tighten it so much and it would slip. Not sure if it was stripped or not, I don't think so.
Burke	28	Upper	Generally harder to do one-handed than some of the other designs, and it doesn't seem to get as secure of a bind at the end. I'm not sure that it was really tight enough to have done the job and it is a lot trickier to use one-handed.
Burke	1	Lower	Worked well.
Burke	2	Lower	Simple application of device. Got extremely tight around the leg.
Burke	3	Lower	Excellent application. No problems, no difficulties.
Burke	4	Lower	It went pretty good, it didn't pinch as much as the ones that twist, but it still pinched.
Burke	5	Lower	Application was very easy. The latching mechanism to tighten the device, once it got to the point where it was tight it seemed to slip. Wasn't able to crank it to the next tooth where I would have wanted it. It slipped a couple times and I finally gave up. I would have liked to have the device tighter than I had it.
Burke	6	Lower	Initial adjustment was easy. Tightening the device was also easy.
Burke	9	Lower	Easy to apply easy to use, got nice and tight. No problems to report.
Burke	10	Lower	It went on very easy, it tightened very quickly. I was very impressed with it.
Burke	12	Lower	Easier to use than the OHT, but at the end it seemed like it was slipping a little bit.
Burke	14	Lower	Device performed extremely well. Was easy to apply.
Burke	17	Lower	It was easy to apply and get tight and ratcheted. Although sometimes when it was sandy, the ratchets didn't lock in, but you just have to keep ratcheting.
Burke	18	Lower	Easy to use and get on. However, wasn't able to get it tight enough, I believe my uniform got stuck in the device and was preventing me from tightening it any further.
Burke	19	Lower	Broke another one, died again.
Burke	20	Lower	Was easy to put on. I kept cranking down on it, but it kept snapping. I don't know if that was the mechanism saying it was tight enough or a defect in the design. It seemed to restrict blood flow, so it works. I liked that one.
Burke	21	Lower	Pretty good device. A little trouble tightening the strap down. Had to actually reach inside the little clutch system to pull the inner rather than the outer section. After I did that the ratcheting was slower possibly due to my finger injury. Mostly near the end it seemed to

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			slip a lot. I made a lot of ratchets that never tightened the device near the very end. Over all it performed well and definitely felt like it occluded blood flow.
Burke	22	Lower	Worked pretty good, no problems.
Burke	23	Lower	Easy to use. But felt like it was not putting pressure through my sleeve.
Burke	24	Lower	Cinches up pretty well. The ski boot buckle actually works pretty well for cranking down. Definitely better than the twisting models. This time it didn't slip very much although it has in the past. This time it seemed to work pretty good.
Burke	25	Lower	As I was putting it on, The first time I lifted up on the release, what I thought was the ratcheting device to tighten down, which actually made the device fall apart. I stumbled around what seemed like a couple minutes trying to put it back together, finally I got it put back together and strapped it down, it was going pretty easy and seemed to do the job.
Burke	26	Lower	No problem whatsoever. Quick, easy. It gave excellent pressure.
Burke	27	Lower	Device was easy to use, easy to get open and get put on. Pinched a lot when you are tightening it down, little painful. I also experienced slippage when tightening it down, it would slip out of the little notches once it maxed out on the pressure. It was also hard to get off.
CAT	1	Upper	Seemed to work well. Had little difficulties.
CAT	2	Upper	Easy application of device. Had a little difficulty securing device into place.
CAT	3	Upper	Works outstanding.
CAT	4	Upper	Worked pretty good.
CAT	5	Upper	Application was fairly simple. The locking mechanism was fairly easy to latch. Maybe the hooking mechanism, the two "C" areas could be a little bit bigger. Because the stick twisted like it was pointing up toward the sky. Other than that, fairly easy to latch.
CAT	6	Upper	Getting it opened up from the packaged condition was tricky. Once it was on my arm, the Velcro was sticking to itself, so it was a little difficult to get it situated on my arm. Tightening it with the turning mechanism was difficult to get it tight enough.
CAT	7	Upper	Found the tourniquet to be a little bit confusing to get unfolded because of the Velcro sticking, but I was able to do it reasonably well. Once I got it on my arm it was quite easy to do the Velcro and do the windlass. The windlass worked pretty well, better than most of the others because it was inside a sleeve. Didn't pinch nearly as badly as the others and I did feel like I was able to get it secured. The securing mechanism for the windlass was quite easy to use. Over all, of the tourniquets with the windlass design, I found this to be the best one.
CAT	9	Upper	Had some trouble opening it and finding the strap to pull it tight. That's what took the most time, but once I figured it out it was easy to apply and got nice and tight. I did have a little trouble turning the bar, but it did get tight. I liked this one.
CAT	10	Upper	I used it before and it seemed to work pretty well, this time something was wrong. I was trying way too hard to get it tight and it wasn't getting tight for me. I think there was a malfunction with the tourniquet.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
CAT	11	Upper	It was very difficult to get on. There were a lot of Velcro straps. It was very difficult to latch, the turning rod kept getting caught in the folds of my uniform. It caused me a lot of problems, took me a long time to get on.
CAT	12	Upper	The device was a little bit difficult to apply, but it worked once I got it applied.
CAT	14	Upper	Had a problem securing the Velcro, while it was wet and sandy. Tried to tension the device and the Velcro would let go.
CAT	15	Upper	It was pretty easy to put on, easy to secure. No problems.
CAT	16	Upper	Went on relatively easy. Took a little while to get the torsion bar into place, but other than that I thought it worked pretty well.
CAT	17	Upper	I had difficulty with one-handed application undoing the Velcro strap in order to apply it. Once I got it on and cinched down it was simple to use and lock in.
CAT	18	Upper	Difficult to get it cinched out far enough without loosing grip often. I don't know how feasible it would be if you were high stressed.
CAT	19	Upper	Went on, tightened, and secured pretty easily.
CAT	20	Upper	Application was pretty easy. I had difficulties finding the tightening strap. But it was able to restrict blood flow and I liked that one.
CAT	21	Upper	Good device. The longer twisting device makes it much easier to get the force that you need on that last half turn, which is often the difficulty with these designs. The only difficulty I had was with the way its packaged with the Velcro taped up. When you can't see its sometimes hard to find the end of that. If there is some way to package it such that you only needed to shake it out and it would fall open, you put your arm in it, that would be better. Or perhaps putting a piece of paper between the two pieces of Velcro during packaging, that would fall away. Then you can Velcro it after you've cinched it down. That would speed up application a little bit. This is a minor issue, overall the device did well.
CAT	22	Upper	Worked pretty good.
CAT	24	Upper	Seemed to work pretty well.
CAT	25	Upper	Went on fairly easy. The only slight difficulty I had was trying to get a grip on it, seemed kind of slippery. Wasn't a lot to grip, but it was probably one of the easier ones to secure the device. Didn't have to fumble with it too much.
CAT	26	Upper	I got it on 180 degrees out and I found it very difficult to spin with that little metal "C" clamp in the way. I didn't like it at all. I felt it took a lot longer than most of the others. Two-handed application may be easier, but one-handed, I didn't feel was smooth and easy to do. Especially if my arm was really blown up. I don't know if I would be able to get it on.
CAT	27	Upper	The CAT was easy to use, easy to open, easy to tighten down. I think that maybe it would be easier if the stick was a little longer and also I've seen problems and experienced them myself with locking the stick into the holder. It is kind of hard to find and it is a little lower. Once you start tightening it down it drops even lower and it is hard to get it clipped in.
CAT	1	Lower	It went on easily. Worked effectively and was easy to secure.
CAT	2	Lower	Easy application. Easy securing of device.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
CAT	4	Lower	Moderate to easy application. A little difficulty with the darkness, twisting the windlass, but I got it tight enough.
CAT	5	Lower	Application was very simple, the Velcro was good. The only problem I had was once I started turning the stick, it caught on my pants. Minor problem. Felt like to go one more half turn would have been a little too much. Once again it was slippery, probably not much you can do about that. Overall, pretty impressed with this one.
CAT	9	Lower	Easy to put on. One problem was the strap on the bar seemed to be too short. I had a problem spinning the bar at first because there wasn't enough slack, but once it got turned it went on pretty tight. Had a little problem with the Velcro that you use to strap the bar down. Other than that, no major problems.
CAT	10	Lower	It went on easy. It tightened up very quickly. I just wish there were more securing spots so you could do a 1/4 turn instead of a full 1/2 turn. Then you can get it secured tighter.
CAT	11	Lower	I didn't have any problems with it. It went on easy and it was easy to secure.
CAT	13	Lower	Fairly simple and easy to use.
CAT	14	Lower	Had no complaints about this device.
CAT	15	Lower	It was easy, no problems.
CAT	16	Lower	Went on easy, tightened up pretty easy, and it was easy to secure.
CAT	17	Lower	It was light weight, easy to apply and easy to secure.
CAT	19	Lower	Worked pretty well from what I could tell. It was easy to put on and it was really easy to secure.
CAT	20	Lower	Application was very easy, I was able to get it on. I was able to get it really tight. I think it restricted blood flow.
CAT	21	Lower	The Velcro came loose on my first attempt at tightening, but after resecuring the Velcro, device worked well. Seemed to provide good occlusion.
CAT	22	Lower	Worked pretty well.
CAT	23	Lower	Felt like it didn't work, but very easy to use.
CAT	25	Lower	Device went on very easily, secured it easily. Felt like it was working. The only thing I had against it, right when I was doing that last 1/2 turn, it felt like it might break on me. I felt like if I had done another 1/2 turn it might of snapped, it felt fragile. It went on tight and easy.
CAT	26	Lower	Relatively simple. No problems applying it.
CAT	27	Lower	Upon tightening it down, I was able to continue tightening until the strap broke.
CAT	28	Lower	It was one of the better twist-on designs. The cinching, Velcro design works real well before you even start twisting. The handle seems to be a lot less slippery than some of the other ones that use the "T" bar. It keeps it up off the leg until you get a good cinch down on it. The capture mechanism is one of the better ones for the twisting types. It is overall a pretty good design.
FST	1	Upper	The aluminum device has very sharp edges on it. I've cut my fingers trying to apply it and get it secured.
FST	2	Upper	Once device got sand in it, it was difficult to tighten. Pretty simple securing of device.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
FST	3	Upper	It wasn't a simple application, it was kind of difficult to strap it down. Problems with the strap and the application with the metal clamp or metal securing mechanism was kind of hard once you get down to the tightness that you need. It kind of hurts the fingers trying to tighten it. Maybe plastic would be better.
FST	4	Upper	Turned the windlass as far as I could turn it. Because of the loops, I had to back it off. I don't think it got tight enough. There was no way to get it all the way around, because it would be too tight.
FST	5	Upper	Application was fairly simple. The pull strap was almost perfectly placed. The locking mechanism worked just fine. It was fairly simple for one-handed application. I liked the device.
FST	6	Upper	Initial tightening was easy, but starting to turn the ratchet, it got snagged on the loops. Then tightening and fastening it to the loops was difficult to do one-handed.
FST	7	Upper	I found the tourniquet easy to apply and reasonably comfortable. However, the notches on the windlass didn't secure the windlass into the loop. I found them to be sharp and it was difficult to get the windlass to catch. I was finding it painful on my fingers. If I had gloves on or cold fingers it would have been very difficult.
FST	9	Upper	This one went on fine, no problems. I did have trouble when it got pretty tight turning, the bar was slippery and I had a little bit of trouble looking for the loop when the bar was slippery. It went on tight, had no real problems except for the bar.
FST	10	Upper	The metal piece was too slippery to turn and hold. Securing devices were very awkward to use. I didn't care for that tourniquet at all.
FST	11	Upper	It was packaged a little tight. I had some trouble getting my arm through the loop. Once I got it on my arm, it turned just fine. I had problems looping the loop around the twisting mechanism and securing the tourniquet. That was difficult and a pain to do with one hand and blindfolded.
FST	12	Upper	The device seemed to be the most efficient as far as light weight and it was quick and easy to use. My favorite as of yet.
FST	13	Upper	I didn't like it because the device is fairly slippery and you had to make sure you had it on the right way first.
FST	14	Upper	I found it difficult to capture the aluminum piece.
FST	15	Upper	I didn't like it. As you are turning it, if you go up or down while you are turning it you can gain or loose. Its cumbersome. The edges are sharp and hard to get into the loops. The loops are too small. It worked, but I didn't like it.
FST	16	Upper	Went on pretty easy. A little bit difficult to tighten and get the capturing device to secure.
FST	17	Upper	Went on easy and twisted well. Had a little difficulty trying to secure the metal piece in the loop.
FST	18	Upper	I liked it. It got good and tight without causing too much pain.
FST	19	Upper	Seemed to go on ok. It was kind of hard to get it secure, but once I did it was pretty solid.
FST	21	Upper	The tightening strap was tightened down so it was difficult to get the device over my hand and wrist and far above the elbow. Despite the fact the strap was too small the device worked well. It was easy to secure. Wasn't quite able to make a final half turn to secure it, but that was just random based on how far that strap was tightened

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			down initially. It is always going to be within a half turn or another as far as to whether or not you can secure it. Over all out of all of the devices I've used so far, this was the best design. The other 2 I had previously used were the McMillan and the TK-4.
FST	22	Upper	Didn't like it.
FST	23	Upper	Very easy to use.
FST	25	Upper	Device was able to go on my arm very easily. Once I got it on my arm I started twisting it, as I was twisting it, had a little difficulty. A lot of sharp edges. Felt like I was going to cut my thumb open a couple of times. Got it to a point where I couldn't get the strap on it, so I actually had to back it off. Not a whole turn, but a half turn and looped it on the other side. I was able to loop it easily at that point.
FST	26	Upper	It wasn't as easy to use as the last one I used. Once you got it tightened up, it took about 3 guys to get it unhooked. To take it off was difficult. Wasn't that hard to put on, I was able to clamp it down pretty quick. It wasn't very intuitive.
FST	27	Upper	Was easy to get on and tighten down. Very painful for the hand turning the tourniquet due to the sharpness of the metal. Also once you tighten it down, it is very difficult to loop and secure the device. Was easily able to get it turned to where it needed to be but it was very difficult to lock it in.
FST	1	Lower	Had difficulty getting it tight enough.
FST	4	Lower	Worked pretty well. Tried to turn the windlass and it turned like the rest of those. It was kind of small so you couldn't really get a good turn on it. Attachment was relatively easy to do.
FST	5	Lower	The device was actually wide enough I didn't have to cinch it down for my thigh which was probably one of the smaller thighs. Once I turned it, got it to the point that I felt it was tight enough I was unable to hook it. The hook was probably a 1/2 inch to an inch away from the loop, there was just no way to hook it, I tried for a little bit. I had to go back a half turn which I didn't feel was adequate tightness and also I couldn't go a half a turn forward to tighten it a little bit more.
FST	6	Lower	The mechanism appeared to be assembled wrong so the initial tightening was difficult. Once that was tightened, very snug fit was possible with the final adjustment.
FST	7	Lower	Found the device easy to feel and understand blindfolded. Easy to get on the leg and tightened. The windlass was relatively easy to use, better than the other ones. I was able to get it fairly tight. All in all, not too bad for a tourniquet with a windlass design.
FST	9	Lower	No problems to report. Easy to put on, got real tight. Easy to use the little metal device to tighten it down and the loops were easy to find. No problems. I liked this one.
FST	10	Lower	It goes on pretty well. The windlass, the stick thing I think is too slippery with the blood analog on it and makes it really hard to secure.
FST	11	Lower	It was easy to tighten down initially, but when I started turning it, it seemed like I couldn't give it another turn, but it seemed like it needed to be tighter.
FST	12	Lower	Went on pretty easily. I didn't have any troubles with it.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
FST	13	Lower	It worked out pretty good until the end where it twisted up and it was hard to find the latches. Otherwise it was a good tourniquet.
FST	14	Lower	Device worked well.
FST	16	Lower	Went on easily. Has the same problem a lot of the tourniquets have with the "T" handle. It just seems that you can't get it tight enough if you don't make your catch.
FST	18	Lower	I liked it. I was able to get it pretty tight, pretty fast. Thought it was a good tourniquet.
FST	19	Lower	That was pretty easy to put on. I didn't like the fact that the turn little part of it was metal. Like a slick metal. The "T" part has a sharp point to it. I'm sure that would be a minor problem, if it were overshadowed by the fact that your leg got blown off. I was able to get it tight. I couldn't tell if it stopped the blood or not, but it felt like it. All in all I liked it.
FST	20	Lower	That seemed to work pretty good, but I didn't think it was the right tourniquet to use on a leg. It did not restrict blood flow, I think.
FST	21	Lower	Device performed well. As always it is a lot easier to apply on the leg than the arm, due to being able to use two hands. The device ratcheted down well, was easy to secure in this case, which is the opposite of the experience I had when I applied it to my arm.
FST	22	Lower	Pretty simple. Pretty easy to use.
FST	24	Lower	Was easy to apply, but it was very uncomfortable and I didn't think I could get it tight enough to actually do anything. Not very favorable on the FST.
FST	25	Lower	Device went on my leg very easy. Tightened very easy. It was tight, felt like I was not able to get another 1/2 turn on it, but when I laid down, it felt like I probably could have gotten another turn. It had felt tight enough until I laid down.
MAT	1	Upper	Seemed to work great.
MAT	3	Upper	This is exactly what it is, it is an advantage. Great tourniquet.
MAT	4	Upper	Had a little problem with the blindfold putting it on. It went on backwards the first time and had to turn it around. Once I got it on the right way, it took me 20 seconds to get it on and it appeared to be tight enough.
MAT	5	Upper	Extremely simple one-handed application. The turning device, the handle was large enough and it was able to tighten the device sufficiently to where I was able to stop blood flow.
MAT	6	Upper	Difficult one-handed to get the clasp connected to the band, but once that was on and tightened, clasping it with one hand was very easy.
MAT	7	Upper	Easy to apply. Did have a little difficulty with the length of the strap. A little awkward to get it hooked, but once I got it hooked, it seemed to work real well. It did pinch a little as it got tight, so I may not have tightened it all the way because of the pinching.
MAT	9	Upper	No problems. Went on easy got nice and tight. Easy to crank. I like this one a lot.
MAT	10	Upper	I like how the clamp thing stayed on my arm. I was able to mess with the straps and get it hooked up correctly. As soon as it was hooked up, the little hand crank thing tightened it up so good and quickly.
MAT	11	Upper	Didn't have any problems other than it seemed to pinch the skin on the left side of the bracket. Other than that it seemed to work fine

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			and I didn't have a problem getting it on.
MAT	12	Upper	Device worked well.
MAT	15	Upper	Its pretty easy to put on pretty easy to tighten. Pretty fast. I lost the clip for a second, it took a little time to feel where to get back into place, but after about 5 seconds then it was pretty easy.
MAT	16	Upper	Went on very easily and quickly. Easily tightened up. Had a lot of discomfort with the pinching other than that it worked well.
MAT	18	Upper	A little difficult to get it to latch, but as soon as I latched it, was easy to get it to tighten.
MAT	19	Upper	It was pretty easy to work. Once you start ratcheting down it seemed to go on pretty readily. It was kind of hard to get it into the securing strap, but it seemed to work alright.
MAT	21	Upper	Very pleased with the performance of this device. Definitely provides sufficient occlusion, to the point of pain. Easy to apply, easy to cinch down and strap. Definitely the best I used so far in terms of ergonomic design.
MAT	22	Upper	Worked pretty good.
MAT	24	Upper	I thought it worked pretty well, it was easy to apply and cinched down very nicely. I liked that a lot.
MAT	25	Upper	Went on very easy. Secured device very easy. The complaint was it pinched a little bit, but that was one of the easier devices I put on the arm. Went on very quickly.
MAT	26	Upper	Was relatively simple and put an excellent amount of pressure in a minimum amount of time. I liked that one a lot. Probably so far, that's my favorite.
MAT	27	Upper	Was easy to open, easy to tighten down. I got very good occlusion. It was fairly comfortable. Good device, I liked it.
MAT	28	Upper	Very easy to use. Easy to set up. Nice uniform force as you are cranking it down, so it doesn't pinch or bind up. Works really well. Works really fast.
MAT	1	Lower	It seemed to work well. Went on easy and tightened quickly and easily.
MAT	3	Lower	Worked perfect.
MAT	4	Lower	Application was relatively easy. The thin strap caused pinching. I probably could have gotten it tighter, but due to the pain of the pinching I stopped it.
MAT	5	Lower	Application was very simple; the crank mechanism to tighten it was very easy to use. However, I was sitting up when I put it on, when I laid down I felt like I probably could have gotten 3 or 4 more turns on the device. I definitely felt like the pressure was not as much when my leg wasn't flexed.
MAT	6	Lower	Initial adjustment was easy. Tightening it was also very easy.
MAT	9	Lower	It was easy to apply. The crank device was nice, it got it fairly nice and tight. I liked this one.
MAT	10	Lower	Once again I think it is the easiest tourniquet to apply with the "C" clamp holding it in place. With the one arm it works pretty easily. The tightening mechanism, that big flat knob to twist, it is not slippery with blood or sand.
MAT	11	Lower	Didn't have any problems with it. I felt a slight pinching on the left side of the solid part of the mechanism. I think it pinched a little bit of

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			my skin, but it worked really well. I like it.
MAT	12	Lower	It seemed to work fine, but it is kind of bulky. I don't imagine it would pack well in a bag. It seemed to be quite efficient if room wasn't an issue. It seemed to work fine.
MAT	13	Lower	It was the easiest I've used so far.
MAT	14	Lower	The device was easy to apply, easy to tension. I could have applied more tension, but my skin was pinched between the tensioner and the band and was causing great pain.
MAT	15	Lower	It is probably the easiest to use, it is probably the easiest to tighten, you don't have to over think it. It is probably the fastest.
MAT	16	Lower	The device seemed to work well and got tight. The only problem is it pinches on the inside of your leg when you are applying it to your leg.
MAT	18	Lower	I liked it. I thought it was pretty easy to use. Pretty simple to get tight. I liked how it latched so you don't loosen it and slip off your fingers and lose the tightness you've already got. Good tourniquet.
MAT	19	Lower	Broke it.
MAT	20	Lower	Application was good. Went on smoothly. I was able to restrict blood flow.
MAT	21	Lower	Excellent device. Again, easy to cinch down easy to tighten the strap down. Ratcheted extremely well. Definitely the best device out of this group.
MAT	22	Lower	Worked pretty good.
MAT	23	Lower	Worked really well.
MAT	25	Lower	As I was putting it on, pulled it up a little bit, continued tightening it down, started to hurt, then the thing snapped. It broke.
MAT	26	Upper	The only thing I had a little problem with was that little "C" clip getting it in there. It popped out after I started turning it, but I got it back in. It was nice and tight tension. Seemed to be no problem.
MAT	27	Lower	Device was easy to get on. Easy to locate all the components. Was able to tighten it down quickly and easily. No slippage. No breaking. Was kind of hard to find the initial loop to lock it down on the plastic lock. The only complaint is it is pretty heavy
McMill	1	Upper	Had difficulty in getting the tourniquet tight enough and could not secure it. Had to loosen it up enough to get a couple more turns on it and still had difficulties securing it.
McMill	2	Upper	The device was extremely difficult to tighten and lock in place.
McMill	3	Upper	It was a hard application to tighten down. Hard time applying to my right arm due to the securing mechanism not strapping properly.
McMill	4	Upper	It was extremely hard to apply. When you did you had to have it in a specific angle to your arm so you didn't pinch it. Other wise it pinches pretty badly and it doesn't get tight enough. I wouldn't recommend this one.
McMill	5	Upper	The application of the device, the pull strap is harder to pull, it is not free moving which made it difficult. The device turns fine if you give it enough slack, but the securing device is incredibly difficult. I probably would have flat out died before I secured it if I didn't have somebody to assist me. Tried multiple attempts to get it where it was tight enough to do some good. I was finally able to secure it. The only other solution would have been to bring it back another half turn

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			which would not have been tight enough to stop blood flow.
McMill	6	Upper	The initial tightening of the device was difficult when clogged with sand. Tightening the tourniquet itself with the twist mechanism was easy, but getting it any tighter was difficult, so it is tough to tell if it is tight enough or not. For clarification, each twist tightens it significantly so to twist it any further would have been difficult. It didn't feel like it was tight enough.
McMill	7	Upper	I found the device to be confusing to do by feel blindfolded and with one hand. When tightening the windlass, I was unable to get it to its full tightness, because of the windlass only being able to secure once every 180°. To find the loop to secure it with, I accidentally tripped the quick release latch and the whole thing sprung open. Without visual aid and one-handed I was not able to resecure the device so I gave up. Over all I did not find the device easy to use. It was too confusing to use by feel.
McMill	8	Upper	Very hard time getting it to tighten.
McMill	9	Upper	I was not impressed with this one, I didn't like it. To get it tight you have to make a good turn so you have to keep it a little loose before you start turning. The bar was extremely slippery. I had trouble using the little slides that held the bar in place. I had to actually reapply it.
McMill	13	Upper	It was ok. It was a little difficult at the end, but it was ok.
McMill	14	Upper	I thought it was difficult to turn the tensioner. And it was difficult to apply enough pressure and still be able to capture the tensioner.
McMill	15	Upper	Was unable to tighten it. Seemed like the size of my arm was in between turns and I wasn't able to get it in the slot. I went the whole five minutes and had to rest a couple times. My hand cramped completely up from turning as hard as I could. I just couldn't get it secured. My hand was wet and kept slipping off the nylon strap and I couldn't get it secured.
McMill	16	Upper	Had a hard time getting the strap cinched down tight enough to start turning the handle. Once I did get the handle turned, just like every other tourniquet with a "T" handle, it was just difficult to get it tight enough to get the blood flow stopped.
McMill	17	Upper	Pretty easy to apply. It was difficult one-handed to secure the rod into the sleeve, it took quite a while to do that.
McMill	18	Upper	Was unable to fasten it in place once I had it tightened. A two-handed operation. I didn't like it at all.
McMill	19	Upper	It is really difficult to secure with those nylon flaps.
McMill	20	Upper	That one, operation was terrible. I don't like that one at all.
McMill	21	Upper	Device was difficult to cinch down with one hand in terms of the twisting mechanism. I twisted the securing device into the twisting bar, which I also did when I applied the device to the leg. This seems to be an issue for me applying the device. Makes it difficult to secure it. I had to actually release the tourniquet, swing the opposite side of the securing device to the bar and then finish securing it. Also it was difficult to occlude blood flow because you can only stop it at a half turn and I really need to go another 1/8 to 1/4 of a turn to get blood occlusion. I couldn't do it because the securing device is only in two locations.
McMill	23	Upper	It was a little hard to use, but it was ok.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
McMill	25	Upper	It was kind of hard to cinch down around my arm. I was able to tighten it pretty easily. Very difficult to secure. I couldn't get it in the loop itself. I ended up securing it, but not in the proper way through like the little tab itself. It was very difficult for me to secure.
McMill	27	Upper	Device is easy to open, easy to get around my arm. Maybe might need to be opened a little more. At first I didn't think I had it through my arm right. It was really hard to tighten down. The stick was really slick and maybe not long enough. It was really hard to get some torque behind it. I wasn't able to twist it more than 1 1/2 times or so. I didn't feel like I got any occlusion from it, but apparently I did. If I had it a little tighter or a little looser I wouldn't have gotten it tight enough, because I didn't have enough movement in the material to tighten it down. Also it was very hard to pull the holders over once it was tight on the arm and to get that lock in one-handed. I had to use my teeth to get it. It did not seem to be a very effective device for using with one hand.
McMill	1	Lower	Seemed to go on well. Had difficulty getting it tight and getting it secured.
McMill	3	Lower	No problems.
McMill	4	Lower	I couldn't get it tight enough. I would have had to pull it up and down and there wouldn't have been enough time to do that. Once you get it down you can't get enough spins on the crank arm. You have to back it off to put it in the little slot that it goes in.
McMill	5	Lower	Application was simple. Once I started twisting the windlass, the pinching became very tight. Seemed like it was tight enough. I imagine if I was in a situation without the lower half of my leg, I could have gotten it tighter than I did. Other than that the device worked fine.
McMill	6	Lower	If you leave enough of a gap once you put it on your leg, between the device and your leg, tightening it with the twisting mechanism is pretty easy. Fastening it with the pull straps is also pretty easy.
McMill	7	Lower	Tourniquet was easy to get over the leg, easy to apply, easy to understand. It had the same problem that all of the windlass based tourniquets have. I reached a point where it was snug and not too tight, but I could not rotate it a full 180° further so I had to secure it with it less than optimally tight.
McMill	9	Lower	Wasn't hard putting on, no problems. Slipping it onto the leg, I did initially tighten it too far and couldn't turn the bar so I had to go back and loosen it up a bit. When I was turning it the bar was extremely slippery, I was having trouble grasping the bar. Once it did get tight, I had trouble sliding the bar holders up because it was a little too tight. So it didn't feel like I got it as tight as I could have if the mechanism had worked. But it did get tight and did work in the end. It didn't seem too easy to use.
McMill	11	Lower	It was easy to get on my leg, but when I was tightening it down, it didn't feel like it was as tight as it could go. I couldn't get it to the next increment, the next half a turn to lock it down, so it didn't seem quite as tight as it should have been.
McMill	12	Lower	I thought it was a piece of junk and I couldn't get it tight enough to occlude the blood flow.
McMill	13	Lower	It was easier to use than it was on my arm.
McMill	16	Lower	It was pretty easy to get started and cinch down, but the "T" bar, it

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			was hard that last turn to get it tight enough for it to do anything.
McMill	18	Lower	It got tight. It had very little play to start with, so I don't feel that I was able to get it tight enough.
McMill	19	Lower	Tightened up pretty well, it almost seemed like I couldn't get the last turn on it, but the securing device seems to hold it pretty well.
McMill	20	Lower	I guess it worked. I don't like it too much because it kind of pinches your skin. But if I got my leg blown off I guess that would be the last thing I would be worried about. Application of it was relatively easy. The only bad part about it, it was not that tight, could only do a half turn and it hurt like a son-of-a-gun.
McMill	21	Lower	Device was easy to initially tighten. Easy to provide what seemed like adequate tightening, however difficult to secure the device after spinning the handles. I was able to feel the locking device on one side, but couldn't get it pulled up close enough to the handle to have it lock and the other side got tangled in the twisting. Important when you are applying to make sure the locking devices are far enough away from the spin bar. In a moment of stress would be an extra step that would seem suboptimal to performance and application.
McMill	22	Lower	Tightened up too fast.
McMill	23	Lower	Very easy to use.
McMill	24	Lower	Didn't really like that tourniquet. Over all I'm much less impressed with the tourniquets that you have to tighten with the toggle and secure. I prefer the tourniquets that have a ratcheting type system.
McMill	25	Lower	Device went on very easily. As I put the device on and started to tighten it down it started pinching the skin real bad. It got to the point where I could get it around I had to back it down a little bit. Once I put it in the holder, when I started lying back, I felt it pop out. Basically it unwound from there, but I was already lying down.
McMill	26	Lower	It was easy to put on. Didn't take that long. Seemed to apply good pressure.
McMill	27	Lower	Very sturdy, very tight. Very hard to get turned that last little bit to connect it into the holder. The holder is also very hard to slide being they are tightened down. They are very hard to slide and lock it in even with both hands. Other than that it was a good device.
MET	1	Upper	Hard to get it tight enough and then secure it.
MET	2	Upper	Easy application. Hard to lock-in device.
MET	3	Upper	Worked great.
MET	4	Upper	It didn't pinch this time, but I couldn't fasten it. All the windlass ones are kind of rough to use. It wouldn't go in the little Velcro fastener so I had to really work to get it fastened.
MET	5	Upper	Application was fairly simple, especially when I remembered where the pull strap was. The turning handle for the tightness was not easy to turn and the locking mechanism, the red strap and the strap with the "D" ring were placed improperly but could not strap it in. Ended up using the black strap with the "D" ring.
MET	9	Upper	This one was difficult to get on. I had a hard time pulling the straps through the bar. It took a while. Once the strap came out of the bar, it was hard to turn. And once it got turned, it was hard to find the loop that the bar goes into. It was able to get nice and tight, just hard to apply.
MET	10	Upper	Worked pretty well except the securing mechanism was difficult.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
MET	11	Upper	It wouldn't cinch tightly on my arm before I started rotating the stick part. It felt like the sand was clogging it up. I couldn't get it cinched tightly, when I started turning the stick, I wasn't able to get it under the loop that secures it in place. I had great difficulty. It didn't seem to stop what flowed into my arm. I couldn't get it tight enough or it was too loose.
MET	13	Upper	I didn't care for it too much. It was really hard to get on.
MET	14	Upper	Tourniquet performed well. I was limited to the amount of pressure I could put on my arm. The tensioning device had to be oriented to be captured.
MET	15	Upper	Worked pretty well, no problems.
MET	16	Upper	It is pretty easy to get on there and get cinched down, but it was very difficult to get the handle secured and in place after I got the tourniquet tightened.
MET	17	Upper	Easy to apply, but difficult to secure the rod.
MET	18	Upper	It was hard to find the slack. Other than that it seemed to cinch down pretty well. It wasn't hard to find a place to lock it in so I liked it.
MET	20	Upper	Application was pretty easy, but I don't like it, because if you twist 1/2 a turn it is too much. If you don't twist it, you don't cut off circulation, so I'm not happy at all.
MET	21	Upper	Difficult finding the strap while blindfolded in order to cinch it down. As with almost all of these devices I had a really hard time getting the bar into the retaining strap. Felt like it occluded blood though.
MET	22	Upper	Worked pretty good, still a little complicated.
MET	25	Upper	Was able to put the device around my arm and tighten it down fairly easily. Once I started tightening I got it tight and it was somewhat difficult to secure, finally got it down. Took me a couple attempts, it was difficult to actually secure the device.
MET	26	Upper	Simple to apply seemed to have a lot of pressure. I didn't have any problem with it at all.
MET	27	Upper	Very awkward, hard to tighten down with one hand. I believe I got occlusion. I had to use my mouth at one point to try and lock it in. Very uncomfortable.
MET	28	Upper	Probably one of the better of the twist-on types. The strap that gets pulled up through the handle gets in the way when you are trying to twist down, but over all it's a better way of cinching up at the beginning than some of the others. I got a real good clamp down on that last turn. It worked pretty well for a twist-on type.
MET	1	Lower	Everything seemed to work well and I was able to secure it.
MET	2	Lower	Easy application. Pretty easy securing of device.
MET	3	Lower	Application was fine. Securing it, application was very easy.
MET	4	Lower	A lot of pinching going on there and it didn't occlude.
MET	5	Lower	Application was very simple to tighten the device initially. The turning stick tightened down sufficiently. The locking devices were fairly easy to use. Could have possibly gotten it a little bit tighter to occlude the blood flow, but the pinching and what-not prevented me from tightening it any more.
MET	6	Lower	Initial adjustment was easy. Tightening the device was also easy.
MET	7	Lower	Found it to be easy and simple to apply, but you have to turn the windlass a full 180° for each increment. When I reached a point that it was not tight enough, I could not make a full 180° turn so I ended

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			up leaving it looser than it should be.
MET	9	Lower	Didn't have any problems, went on nice and tight. Easy to apply. Easy to use the little bar and easy to find the little hook. This was a good one.
MET	10	Lower	It went on pretty easily, but I had a really hard time getting tight enough to secure it. I could get it where it was tight, but I wasn't able to secure it down. The only place that I could secure it down just wasn't tight enough. It is almost like it needs another securing point or something.
MET	11	Lower	The tourniquet went on easily with both hands. I didn't have any problems with it.
MET	12	Lower	That device worked really well.
MET	15	Lower	It was easy, I didn't have any problems.
MET	16	Lower	Went on easy tightened up really easily. Thought it worked really well.
MET	17	Lower	Simple to apply, get tight, twist and latch. Easier than the FST.
MET	18	Lower	I was able to get it tight fairly quickly and lock it in.
MET	19	Lower	It broke.
MET	20	Lower	Application was pretty easy once I found the tightening strap and I think I restricted blood flow. Only thing I didn't like is if it goes too tight you have to back it up one half a turn and that could be the difference between restricting blood flow and it working or not working.
MET	21	Lower	Device was easy to apply. However again, difficult with all of these twisting devices to get that last half turn you need to secure it. So definitely didn't feel like it occluded.
MET	25	Lower	Got the device on fairly easy, rolled it up over my leg, and cinched it down very easy. Started tightening, once I got it as tight as the device could get, I had problems trying to secure the device in a position where it was supposed to go underneath the loop with the Velcro. I was able to get it under some loop, not too sure, I don't think it was the right loop. I had the bar there so it wouldn't unwind. There was difficulty in securing that device. I had to back off on it and tighten it back down to try and find the loop.
MET	26	Lower	It was easy to use, easy to get on. I just forgot the little pull thing was on the top of the twisting bar. So with my blindfold on it took me longer than it should have. With me practicing a couple of times I would have been able to do it fairly easy. It did apply good pressure. I could definitely tell it was going numb.
MET	27	Lower	It was kind of difficult to turn and tighten down. I got it as tight as I could. I think the twisting fabric is kind of bulky. I was not able to occlude blood. Negative on that test.
MET	28	Lower	Probably one of the better designs that you have to twist up because of the nylon panel that's shielding the twisting area from your legs. It clamps down really fast, doesn't get bound up in the BDU's and you can get a pretty good twist by the time you lock it down compared to some of the other twist-on designs.
NATO	1	Upper	Had difficulty getting it tight enough and getting it secured.
NATO	2	Upper	Difficult application. Difficult locking device in place.
NATO	3	Upper	Application was very difficult. It was hard to apply pressure and to secure device on my arm.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
NATO	4	Upper	The application was hard you had to wrap it around twice. It's a big wide band, it doesn't work well. The metal fastener, I couldn't spin it around fast enough to occlude, I probably could have gotten it, but it was a pain.
NATO	5	Upper	The initial application was fairly simple. Had a little trouble differentiating between the free moving ring and the fixed ring. Was able to crack that while twisting the device. When it became difficult to twist the device, it wasn't stopping blood flow the way I thought it should. Tightened it as tight as I could, but knew that it wasn't sufficient. Too much material bunches up. Possibly if there was a second person applying the tourniquet, not the wounded person, they would be able to tighten it enough to stop blood flow. Pretty difficult for just one person one-handed.
NATO	6	Upper	Initial adjustment was tricky. I ran out of slack so I had to readjust. Tightening it completely on my arm with one hand, and getting the clasp to fasten into the ring with one hand was very difficult.
NATO	7	Upper	The device was a little bit confusing to apply. It was difficult to find and secure the rings blindfolded. Was difficult to get the windlass engaged in the ring and I was not able to tighten the tourniquet well with the windlass. I reached a point where it was tight, but not as tight as it could be, but I couldn't turn it a full 180° so I had to leave it secured without it being as tight as it could be. It was also difficult to engage the locking ring. Over all I felt this was not a very easy-to-use device.
NATO	9	Upper	This wasn't too bad. I had some trouble, took me some time to find the second loop. It got nice and tight, just had some trouble finding the bottom ring, other than that, no problems to report, so it was ok.
NATO	10	Upper	I think it is kind of an awkward device trying to get it to work. It just doesn't feel like it gets tight enough. Another whole turn would be too tight. It is a pretty awkward device.
NATO	11	Upper	I had a lot of trouble turning it that last turn. Once I got it turned it was a very difficult process getting it locked into that ring. This was a real difficult device to use this time around.
NATO	12	Upper	I could not get the device tightened with one hand and being blindfolded in the allotted amount of time.
NATO	13	Upper	Was really difficult, just getting the rings and everything in there. I don't think it stopped the blood flow to my arm. I wouldn't recommend it.
NATO	14	Upper	Device was difficult to capture and difficult to tension. Also difficult to capture after it was tensioned.
NATO	15	Upper	I for some reason twisted the ring instead of the part I was supposed to twist and I couldn't get it secured and when I did get it secured I had to loosen it and it wasn't tight enough.
NATO	16	Upper	The main problem with the NATO is it is an all or nothing kind of thing. If you can't get it to turn the extra turn it doesn't seem to be cutting off the circulation.
NATO	17	Upper	The loose ring was a little difficult to find with my one hand to lock it in place. Other than that it worked pretty well.
NATO	18	Upper	It was really difficult to get set up. Then it was hard to keep it tight while fixing it in place.
NATO	20	Upper	Application was fairly easy. Trying to maneuver those rings can cause some problems especially if a person is panicking or in a

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			hurry. I don't know if it had a tight enough grip, but it was alright.
NATO	21	Upper	Had difficulty learning the application technique of the device before even applying it. May be due to my limited mechanical skills. Upon trying to apply the device while blindfolded, I grabbed the end of it as it was presented to me which was one of the rings. Flipped it open and I began to try to apply it. However the loose ring apparently fell off during the part where I was unwinding it. Obviously if you are blindfolded or unable to see while trying to apply this, in a worse case scenario, you would never know that that ring had fallen off and would be unable to secure the tourniquet. Kind of hard to accept this tourniquet over all as I was unable to apply it.
NATO	22	Upper	Very complicated. Took a long time to figure it out.
NATO	23	Upper	It got loose when I was applying the pressure.
NATO	25	Upper	Device was able to go on very easy. Once I started it was very difficult to secure. It seemed like it wasn't tight, but I wasn't able to get another 1/2 turn to get it tighter. I was only able to get it half way through and felt like I would have to rip my arm off just to get it that other 1/4 turn. So I had to back it off so it didn't feel like it got tight enough.
NATO	26	Upper	It took me a while fumbling with the ring. I had to be instructed how to use it again, because if you are blindfolded and the free ring slides down underneath it and you can't really see it you are trying to hook it in, it won't go. You have to slide it back out and retighten it. I didn't like that one at all. I don't think it is worth pursuing any farther.
NATO	1	Lower	Application was easy and everything seemed fine.
NATO	2	Lower	Device easy to apply. Could not tighten device down as far as I thought it could go.
NATO	4	Lower	Horrible design. That's the second time I've applied it and it pinches more than it occludes.
NATO	5	Lower	Easy to apply, not complicated at all. A little issue with getting it tight enough. If you go a little too far, you cannot latch it. If you don't go far enough, you can latch it, but it doesn't seem tight enough.
NATO	6	Lower	Initial adjustment was easy. Tightening it was easy. Securing the clasp to the 2nd ring was cumbersome.
NATO	7	Lower	I found it easy to apply, simple to operate. It did pinch the skin where the windlass turned and I had to stop tightening because of the pain of the pinching rather than the feeling of constriction of the entire thigh. Suspect it did not fully occlude.
NATO	9	Lower	Didn't have any problems with this one. It went on easily. Easy to use. Did pinch a bit, but really doesn't matter, it's a tourniquet. No problems.
NATO	10	Lower	I got it on no problem. Had a bit of trouble securing it. It took me a little while. Other than that it worked fine.
NATO	11	Lower	Had no problems with it. Pinched the skin a little bit when I was turning it.
NATO	12	Lower	Device didn't work as well as I hoped it would have. It was pinching my skin and it was difficult to apply.
NATO	15	Lower	It was horrible. My leg is all bruised up and I don't even know if it was tight enough. If I did get shot in the leg, I might do that, but other wise it's definitely not worth it. It was horrible.
NATO	16	Lower	It went on rather easily, but the aluminum twisty thing was hard to get into the ring.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
NATO	17	Lower	Fairly easy to apply, but it tightened up with severe pinching. Makes it difficult to get it tight.
NATO	18	Lower	A very simple one. Got good and tight, didn't have to worry about my hands slipping off. A little confusing at first to remember to slip through the 1st "D" ring. Other than that it was a good tourniquet.
NATO	21	Lower	Was difficult to get device applied and excessive pain for the degree of occlusion it provides. Not an efficiently designed tourniquet.
NATO	22	Lower	Didn't like it. It pinched.
NATO	24	Lower	The study was halted. When I opened it, one of the "D" rings fell off away from the tourniquet and there was no way to secure it. There definitely needs to be a better way to secure both rings to the device.
NATO	25	Lower	I was able to put the device on my leg fairly easily. Started tightening it down and it really pinched the skin a lot. It hurt, but I was able to get it on and secure it fairly easily. Just a lot of pain in the process.
NATO	27	Lower	I did not like it at all. The device was very awkward, hard to figure out even after prior training on it. Was very hard to get set up. Twisting it pinched severely and I tightened it down as much as I could even more than most people probably would and had a very hard time getting the ring to lock in because there is so much material lifting up the twister. Also I didn't have complete occlusion and it took me a lot longer than it should have.
NATO	28	Lower	Went on pretty easy. Probably the only problem is the BDU's start to twist up in the strap as you are going and you have to keep it out of the device to get a good last couple of turns on there. Otherwise, it worked real well.
OHT-2	1	Upper	Had difficulty cinching it down tight enough.
OHT-2	2	Upper	Was easily applied, but there was some level of difficulty tightening the device. It kept loosening when I was pulling the strap with one hand.
OHT-2	3	Upper	Easy application, but just not tight enough.
OHT-2	4	Upper	With one hand it is kind of hard to cinch back and forth. I could barely do it. I couldn't get it tight enough. It might work if it wasn't wet and sandy. However, it bound up in the catching device.
OHT-2	5	Upper	Application was fairly simple, not complicated. The pull strap to tighten the device seems to be a little too long, loosing strength as you are pulling getting along a little further away. Once I had it pulled as far as I could I came back and tried to tighten it and was unable to tighten it much further. Other than that the device worked pretty well.
OHT-2	6	Upper	Initial adjustment was easy. Getting it good and snug was easy, but I'm not sure the device was tight enough. I tightened it as much as I could.
OHT-2	7	Upper	It was a little bit confusing to apply, trying to figure out which band to pull. I was eventually able to get it snugged down. It was more comfortable than some of the other devices because it didn't bite into the skin. It had a more uniform pressure, but I wasn't sure if I got it completely tight. Wasn't able to get it any tighter.
OHT-2	9	Upper	I didn't like this one it was too large for the arm and it was hard to find where the handle was. Once I did, it went on ok, but I had a little trouble getting the Velcro off with one arm. Then pulling the handle to tighten it was ok but it didn't get tight enough. When I got it as tight as I could to pull both sides, I tried to pull one and it just loosened up. Not hard to apply, but hard to tighten and couldn't get

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			tight enough.
OHT-2	10	Upper	Thought it was kind of cumbersome to get it tight enough, then I wasn't sure if it was tight enough to occlude blood or not.
OHT-2	11	Upper	I couldn't seem to get it any tighter than it was. It didn't seem to be very tight on my arm at all.
OHT-2	12	Upper	Seemed to work just fine. It was a little difficult to get tightened up in a hurry, but once I got it tightened up it was no problem.
OHT-2	13	Upper	It was about as easy as it was to use on my leg.
OHT-2	15	Upper	It was easy to get on and operate.
OHT-2	16	Upper	I had no problems with it. It seemed to tighten up pretty quickly. Other than that, it didn't get very tight. That's the only problem I saw with it.
OHT-2	17	Upper	Blindfolded and one-handed, it was difficult to know which ones to pull and tighten. It was comfortable, but it didn't tighten as well as some of the others.
OHT-2	18	Upper	Could not get it tight enough.
OHT-2	19	Upper	Cinched it down, don't think it occluded blood flow.
OHT-2	20	Upper	Application was relatively simple, but if a person was in a hurry, I think they would have difficulties trying to apply it. I don't know if it stopped the blood flow or not. It didn't feel like it did.
OHT-2	21	Upper	Device very easy to apply. Easy to tighten down. However, unable to tighten it down sufficiently to feel like I occluded blood flow. In terms of ergonomic design it was very good.
OHT-2	22	Upper	Didn't like it.
OHT-2	23	Upper	It was very hard to use.
OHT-2	24	Upper	Worked pretty well, cinched down easily. Didn't get too confusing. The only thing I could see is if you really had decreased visibility. When it comes out of the wrapper it could be easily misapplied to the arm if it got twisted around. Other than that I thought it was a good device.
OHT-2	25	Upper	Device went on very easily, seemed to tighten it down very easily, I just don't know if it was tight enough to stop blood flow. It didn't feel like it was tight enough, but again, I don't know what the results were.
OHT-2	27	Upper	I felt I was unable to get enough leverage on it to tighten it down. I didn't feel that I had blood flow restriction. It was easy enough to get on and easy to find and the Velcro was easy to get a hold of and pull. It's a good initial start for the tourniquet but I think it needs a secondary tightener on it.
OHT-2	1	Lower	Went on very quickly and easily. I couldn't really tell whether I had it tight enough and it was difficult to get it even tighter.
OHT-2	2	Lower	Easy application. Easy tightening of device.
OHT-2	3	Lower	Can't secure it tightly. Need to have a mechanism once you get it secure to crank it down enough to stop the blood flow. Didn't feel any kind of pressure on my leg at all.
OHT-2	4	Lower	Didn't work.
OHT-2	9	Lower	It went on real easy, no problems. I got to snug it down nice, no problems. I felt like it couldn't get tight enough. I was cranking back and forth and tried to get it tight, but it wouldn't get as tight as I wanted it too.
OHT-2	11	Lower	Initial difficulties figuring out where to unvelcro it and where to pull. Once I got it on my leg, I tightened it a far as I could but it didn't seem

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			to be as tight as it should be.
OHT-2	12	Lower	The device seemed to work pretty well. I didn't have any problems with it at all.
OHT-2	13	Lower	It's the best tourniquet I've used so far. It was easy to use and stopped the flow, I'm pretty sure.
OHT-2	16	Lower	Went on easily, but it was very difficult to get it tight enough.
OHT-2	17	Lower	It was easy to apply and get tight. Although you can only get it so tight. Wasn't able to ratchet it enough to cut off circulation.
OHT-2	18	Lower	It didn't feel like I could get it anywhere near tight enough.
OHT-2	19	Lower	I broke it, so it didn't work for me.
OHT-2	21	Lower	Application was very easy. Quick to apply, quick to tighten down. The only possible issue was I didn't feel like I could tighten it enough to occlude blood flow. It wasn't quite painful enough when applied versus the types that have a twisting application that you could crank down. In terms of ease of application and being able to get it up high enough on my leg, it was very good.
OHT-2	22	Lower	Pretty easy to put on.
OHT-2	23	Lower	Didn't like it.
OHT-2	25	Lower	Device went on very easily. Was able to tighten it down very easily. When I was tightening it down, it didn't seem like it was tightening down anymore, I was pulling with both arms on one side, it just seemed like it was slipping around. That was all I could get it.
OHT-2	26	Lower	Very easy to put on. Fairly diver-proof. Easy slide-on cinch-up tight as you can. I don't know how it performed on the Doppler, but it was real easy.
OHT-2	27	Lower	Very easy to open. Had a little bit of trouble finding the Velcro holder thing to figure out what I was supposed to pull on. Maybe held me up about 10 seconds. Rocked it side to side, pulled it as tight as I could, got my arm in there to tighten it. Did everything I could to tighten it. I believe there was still blood flow left after that. Good idea of maybe a secondary tightener would be beneficial for that.
Q	1	Upper	It went on relatively easy, seems that I kept hitting the release button. It was hard to tell whether I had it all the way as tight as I could get it.
Q	2	Upper	Easy application. Had difficulty locking device in place.
Q	3	Upper	Complications due to application on right arm. Tourniquet seemed to work fine.
Q	5	Upper	Application was pretty easy. The ratcheting mechanism got a little jammed with the sand and the grit. Other than that I was able to tighten it to a point that I felt was sufficient to stop blood flow. It cinches down pretty easy. The only trouble I had was with the pull strap which initially tightens the device. It loosened a little bit as I started to ratchet. I had to block the device with my leg, hold it between my arm and my leg to keep it steady to start ratcheting.
Q	6	Upper	Device is a little bulky. Once it is on the arm, tightening with the ratchet mechanism is easy.
Q	9	Upper	Had trouble getting it on and getting it to tighten.
Q	10	Upper	I thought it was very clumsy to tighten up with the strap. The strap kept slipping. I had to hold the ratchet part with my legs to try to tighten it up and I couldn't get it tight enough when I started ratcheting. I thought it was very clumsy and I did not like this device.
Q	11	Upper	It went on my arm easy enough, but I couldn't find the strap with the

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			plastic piece to pull on initially to tighten the tourniquet. After that I had a little bit of trouble reaching around the other side of my arm to operate the final cinching mechanism. Other than that it worked fine.
Q	12	Upper	Device worked fine. My only complaint is that it is a little big and kind of bulky.
Q	14	Upper	Device worked well.
Q	15	Upper	It was probably the fastest time I've had yet. It was easy to apply and easy to get tight. It was pretty uncomfortable, but I guess that wouldn't matter.
Q	16	Upper	It went on rather easily and tightened up easy also.
Q	17	Upper	It was heavy and bulky and difficult to operate without wedging the jam into your leg.
Q	18	Upper	I managed to put it on. I grabbed the metal bit not the plastic handle therefore it ended up in the wrong hole. So I had to take the tourniquet off and redo it.
Q	19	Upper	BDU blouse got sucked up in the winching mechanism. It was twisted somehow so no matter what I did, there was no way it was going to get tight enough to occlude blood flow.
Q	20	Upper	Thought I had it on there tight enough when I started ratcheting, but apparently it wasn't tight enough so as I was ratcheting it came to the end of its limit and it still wasn't tight enough so it failed. This may be a problem in the future.
Q	21	Upper	Very difficult to get that strap tightened down. Long application time. The ratcheting worked fine once I got the thing cinched down tight enough, but very difficult to get that accomplished. There are definitely easier devices to apply in terms of getting that initial strap tightened.
Q	22	Upper	Didn't like it. Too big for the arm.
Q	23	Upper	The initial cinching buckle was kind of tight so it's a little tougher than some of the other rigs to get cinched up ready to go, but once you get it in there then the ratcheting mechanism works very well. It is a little better than some of the others where you have to go 180° to get around to the next notch so it is a little easier to cinch it up to the tightest spot.
Q	24	Upper	Thought it worked well, it was easy to apply. And it cinched down pretty easily with that ratchet device. I liked it.
Q	25	Upper	As I was trying to put the device on, it was kind of difficult to cinch it up tight around my arm. I had to pinch it in between my right leg and my arm and try to strap it down with my hand. But I was finally able to do so. I cinched it down. Device secured very easily once it was tightened on my arm. Once it was on and cinched down, it seemed to stop the blood flow.
Q	26	Upper	With minimal instruction and no practice I was able to put it on in about 30 or 40 seconds. I found it relatively easy. The only thing is it was a little bulky. Other than that it is real easy to use. If you've ever used a cargo strap, you can figure it out in less than a minute so training would be very easy and quick for the fleet.
Q	27	Upper	Device was easy to open easy to get your arm through. Kind of hard to tighten down maybe due to the sand initially and also when I started ratcheting I was only able to get to a certain point maybe the clicks were a little too big. Maybe some smaller locks would be maybe beneficial because too much room between each lock. Fairly

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			comfortable. I felt like I got occlusion.
Q	1	Lower	I unbuckled the device, wrapped it around my leg and buckled it back. Everything seemed to work with ease and speed.
Q	2	Lower	Simple device. Pretty severe pinching with the skin when you ratchet the device down.
Q	3	Lower	Easy application. Very firm, very tight when applied to my upper leg.
Q	5	Lower	Application was very simple. Ratcheting was good. Would have liked to have gotten it tighter than I did. Tried 3 or 4 times to get it tighter, but it didn't seem to move, the ratcheting portion wasn't moving at all.
Q	6	Lower	The initial step was easy. Tightened it as tight as I could, the device wouldn't tighten any more. But I was in no pain, so I am not sure the device was tight enough.
Q	8	Lower	I was able to put the latch on and tighten it above my right knee cap with no problems what-so-ever.
Q	9	Lower	Had trouble getting this on, I had my leg in the wrong loop. I could tell right away that it was in the wrong loop, because it was too tight and I couldn't loosen it, so I had to take it off and reapply it. After that it went on pretty easy. It got nice and tight, no problems to report. This one was a good one.
Q	12	Lower	That device worked well.
Q	13	Lower	Easy to put on, was quite painful, but did the job.
Q	14	Lower	Performed well and was easy to tension.
Q	16	Lower	It was pretty easy to get on and get tight. The only issue I had with the tourniquet was it was real hard to get it tight without pinching the skin.
Q	17	Lower	It was very easy to install, get tight and ratchet. Just a little awkward and heavy.
Q	18	Lower	I didn't get it tight enough. It was hurting a lot. Otherwise very easy to use.
Q	21	Lower	Device worked well. Much easier to cinch down than the Burke. Definitely ratchets down well like the majority of the ratcheting devices.
Q	25	Lower	Got the device, put it on my leg fairly easily. Had a slight difficulty finding the strap, because there was no tattle tail end to grab it was flush up against the metal buckle. Finally found it and pulled to tighten it down. Again went on fairly easy, tightened fairly easy hurt a little more than others as far as pinching the skin, but went on and stayed secured very easily.
Q	26	Lower	It was easy, simple, just like when I used it on my arm. I think it was effective. It was painful.
SOFT-T	1	Upper	Had difficulties getting it as tight as I wanted it and then being able to secure it. I had to back it down one in order to secure it.
SOFT-T	2	Upper	Easy application securing the device.
SOFT-T	3	Upper	It did secure, but the securing mechanism should go on the inside of the arm instead of the outside. That needs to be made known, when personnel are applying tourniquets.
SOFT-T	4	Upper	This one works great except for the way you stop the windlass from moving around. It took me probably a minute just to get that little triangle hooked. If they change that it would be alright.
SOFT-T	5	Upper	The application was fairly simple. The locking mechanisms could be a little easier, maybe differently spaced. The winch seemed to turn

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			to one side making it difficult to secure on the one end. One end was too short, one end was too long to make it easy to secure.
SOFT-T	6	Upper	Putting it on was easy, but tightening the device and securing it in the triangular clasp was cumbersome and difficult.
SOFT-T	7	Upper	Found it to be easy to apply, easy to understand. Same as the others with the windlass, you get to a point where it is tight but not quite tight enough, but you can't turn it a full 180° then it is too tight. So you end up fastening it not quite as tight as you can tolerate. Same problem with all the windlass design tourniquets.
SOFT-T	8	Upper	The difficulty I had was pulling the strap tight and putting the lever into the holding device.
SOFT-T	9	Upper	Went on ok. Snugging it down was ok, but I had a lot of trouble tightening it down. Seemed like there should have been a little more play in the strap. I got it as tight as I could, but I couldn't crank it over to get it latched so I had to back it off. Then it was a little too loose so it was a problem.
SOFT-T	10	Upper	It went on alright, it gets pretty tight, but there is just no way to secure it. I thought the securing mechanism was poorly designed. I couldn't get it secured so I had to go back a half turn to get it secured. I don't think it was tight enough.
SOFT-T	11	Upper	Pretty difficult to get on. I had twisted it one way and I wasn't able to ratchet it into the triangle piece and the triangles on the other side had gotten twisted under my arm, so I had to untwist it and turn it back around the other way. It took me quite awhile once I got it turned to lock it into the triangle piece that was available.
SOFT-T	13	Upper	It was ok, it was easy to use, but I still wouldn't recommend this one.
SOFT-T	14	Upper	Device was difficult to tension and hard attachment.
SOFT-T	15	Upper	I had a hard time getting it secured. It was slippery and I couldn't get it into the triangle cause my arm was in between turns and it was hard to cinch it with one hand and get it into the triangle.
SOFT-T	16	Upper	I found it very difficult to get secured in place, especially on the last quarter turn or so. It was very difficult to get it inside the securing ring portion of it.
SOFT-T	17	Upper	Application was pretty easy, depending on how much arm got blown off. I kept using my arm to cinch down or tighten the excess strap. I don't know if I could do that if I didn't have an arm there to begin with. Application was pretty easy, but I couldn't get it as tight as I wanted too. I had to back off a half a turn because the little part you put in the triangle latch thing, shifts as you turn. So that kind of hindered me and there was blood flow. I didn't like it.
SOFT-T	18	Upper	Was able to get it really tight, it was just a little difficult to secure.
SOFT-T	19	Upper	Broke it.
SOFT-T	20	Upper	Application was fairly easy. I couldn't get it as tight as I wanted to because of the difficulties I was having with the already twisted fabric. So I had to back it off a half turn and it didn't restrict blood flow.
SOFT-T	21	Upper	Strap cinched down pretty well on this one compared to some others. The big problem with this device and devices of this sort continues to be securing the twisting bar. Extremely difficult to cinch that down. Took a long time to apply. Definitely felt like I got occlusion.
SOFT-T	24	Upper	I found the device hard to secure. It is kind of a critical thing. I didn't really think very highly of that tourniquet.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
SOFT-T	25	Upper	I was unable to secure the device to my arm. I could have probably loosened it up and secured it, but I don't think it would have stopped blood flow. I didn't care for it. I was unable to secure the device in the correct manner to my arm.
SOFT-T	26	Upper	It was easy to apply, gave good pressure. I could really tell it was tight. No problems.
SOFT-T	1	Lower	Easy to apply, but difficult getting it tight enough and getting it secured.
SOFT-T	2	Lower	Easy application. Easy locking device in place.
SOFT-T	3	Lower	Worked excellent.
SOFT-T	5	Lower	The application was very simple. Very easy to tighten the device. The two hooks that you put the stick into seem to favor one side once you start twisting. The bulk of the material goes to one side, which makes one of them not available. The stick is pushed to one direction so much that it is difficult to put it in. Too long on one side and too short on the other. Other than that the device was fine.
SOFT-T	8	Lower	That seemed to work just fine.
SOFT-T	9	Lower	Had no problems, nothing to report.
SOFT-T	10	Lower	I thought it was very effective and got very tight. I actually liked the locking mechanism. I thought that was very effective.
SOFT-T	11	Lower	Went on fine. Didn't have any problems with it.
SOFT-T	12	Lower	Worked fine, but it seemed like I had a hard time getting it tight.
SOFT-T	15	Lower	It was easy. Easy to get on. Quick and pretty painless.
SOFT-T	16	Lower	I had no issues with it. It went on relatively easy and it tightened easily also.
SOFT-T	18	Lower	I was able to get it really tight. It was a little difficult to lock it in place.
SOFT-T	19	Lower	Easy to get on. The ratcheting mechanism worked pretty well and seemed easy to secure it.
SOFT-T	20	Lower	Application was pretty easy, however, if you are caught in between half turns, that could be the difference between cutting off blood flow and not. I myself had to go back a half turn which did not constrict the blood flow completely.
SOFT-T	23	Lower	Very easy to use.
SOFT-T	25	Lower	Was able to put the device around my leg very easily and tightened it very easily. Cinching it down was a little painful, not too bad. Tightened it down, seemed like it tightened down real easy. When I secured it in the little triangle fold it felt like it was going to come off. It never did, but it felt like it barely fit in there. The device held on.
SOFT-T	26	Lower	No problem. It didn't seem as tight as some of the others. I felt if I could get one more turn on it, it would be as tight as some of the others, but I just couldn't get it hooked in secondary to pain. I just couldn't get that one more turn. I don't know what the Doppler results were.
SOFT-T	27	Lower	Was easy to open, easy to get on. Was able to tighten it quickly. Got it tightened down fairly comfortably without too much pain. Had good blood occlusion. Was fairly easy to lock down.
SOFT-T	28	Lower	Goes on real easy. Good mechanism for cinching up, but probably for twisting it is the easiest to lock but it has the same problem as all the twist designs. You can only secure it every 180°. If you are lucky you get a nice good cinch right at the end otherwise you are

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			stuck between not enough and too much.
TIAX	1	Upper	Went on easily, seemed to take forever to tighten up though.
TIAX	3	Upper	The tourniquet broke as I was tightening it down with the torque mechanism.
TIAX	4	Upper	Application was kind of hard when it was wet and sandy. Had to turn it a couple of times other than that I think it stopped the blood flow.
TIAX	5	Upper	Application was a little bit difficult. The "D" ring didn't slide as easily as I wanted it too. I had to brace it against my leg to get the proper traction so I could pull on it. Also once I got it cinched up and started to turn the wheel it was a little bit slippery. When it is windy and sandy the wheel may be too slippery, maybe rubber on the handle that flips out would make it easier under adverse conditions. Also tighten to the point that I didn't want to tighten it any further to occlude the vessels, but the turn-wheel popped off.
TIAX	6	Upper	Initial adjustment was a little tricky, but not difficult. Tightening it in a clockwise direction with the wheel was very easy, there was no pain and circulation appeared to stop well.
TIAX	7	Upper	Found the tourniquet a little more confusing to apply blindfolded having to check the orientation of the different things. The handle and strap and everything. A little difficult to get the strap pulled tight without being able to use the other hand. I did like the broader band and the ability to fine tune the tightness. I felt like I was able to get this tourniquet tighter than the others. It probably occluded blood flow better, because it was not as painful to tighten up and I could do it in smaller increments.
TIAX	9	Upper	This was a nice tourniquet. It went on easy, no problems. Tightened down nice and tight, no issues I liked this one.
TIAX	10	Upper	I thought it went on pretty easily. I did have a little bit of a hard time cinching it up one-handed, but as soon as I cinched it up with the wheel mechanism, it got tight quickly and easily. I thought it was a pretty good tourniquet.
TIAX	11	Upper	Went on without any problems, but when I was using the practice tourniquet I rotated it counterclockwise and it broke almost immediately, but when I actually applied it I had no problems.
TIAX	12	Upper	Device worked very well.
TIAX	13	Upper	It broke before I could even use it.
TIAX	14	Upper	Device was difficult initially to tension. Once I had the tourniquet in place with tension on it the secondary tension device worked well.
TIAX	16	Upper	It broke about half way through the evolution.
TIAX	17	Upper	Found it simple to apply. The ratcheting was simple, but it took a lot of revolutions to get it to tighten.
TIAX	18	Upper	I didn't like it. It started out very easy to use, but I broke it before it was even close to being tight.
TIAX	19	Upper	Easy to apply, tightened up real well, but was slow to tighten up. Can't tell whether it cut off circulation or not.
TIAX	20	Upper	Only problem I had with that was trying to take out the slack and the tourniquet ended up being upside down. I still was able to do it, but I didn't like the design.
TIAX	21	Upper	Difficult to secure the mechanism one-handed and it takes a long time to cinch down that thing with the cranking mechanism. But it occluded fairly well.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
TIAX	22	Upper	Worked really well.
TIAX	24	Upper	I thought worked pretty well. It was easy to secure easy to tighten. I felt like it worked pretty well and occluded.
TIAX	25	Upper	Device went around my arm, tightened around my arm, and secured around my arm very easy. Easy to operate. Maybe just a little difficulty tightening because my hands were wet and sandy. But it went on very easy and secured very easy with little pain.
TIAX	26	Upper	Relatively simple to use, I didn't have any problems.
TIAX	27	Upper	Actually got it on backwards and when I was tightening it, it went the wrong way and it broke. Kind of hard to get tight initially.
TIAX	1	Lower	It broke before I even got it on.
TIAX	2	Lower	Fast application. No problems whatsoever.
TIAX	4	Lower	Functioned easy, but it seemed like the plastic pieces probably would break.
TIAX	5	Lower	Application fairly simple. Pull strap works easily. The turning device may be a little difficult when slippery and sandy. The handle could be modified a little bit to possibly be a little bit bigger. The pull out handle that pops up not the big turning wheel. Also the device turned quite slowly. I had it quite snug with the pull strap, when I went to turn the device it seemed to take a lot longer than I expected it too. Approximately 20 revolutions until I felt like I occluded it.
TIAX	6	Lower	Making the initial adjustment, I pulled on it and the device failed.
TIAX	7	Lower	Fairly easy to apply. The only difficulty I had was when I did an initial tightening of the strap and then was not able to loosen the strap in order to reposition the tourniquet higher up on my thigh so it may not have been as high on my thigh as it should have been. I did find it easy to apply, easy to tighten down. It seemed to be effective.
TIAX	9	Lower	Didn't have any trouble getting it on. Had some trouble finding the little lever that is attached to the turn device. Once I got it, it was easy to turn but it didn't get tight enough and it broke. It didn't feel like it was tight enough.
TIAX	12	Lower	Very comfortable. Easy device to use. It was very pleasant.
TIAX	13	Lower	It was very easy and it cut off the blood flow really well.
TIAX	14	Lower	The device was easy to use and performed well.
TIAX	15	Lower	The easiest one I've done so far. Easy to apply, tightened up quick. Unlike all the others it didn't pinch, which I guess wouldn't matter if you just had your leg blown off.
TIAX	16	Lower	Went on easily, tightened down easily. Had no problems with it.
TIAX	17	Lower	Simple to install. A little heavy. Simple to tighten up. Took quite a bit of revolutions to get it to tighten up completely.
TIAX	18	Lower	Broke it before I could get it applied.
TIAX	19	Lower	Broke, doesn't work, don't like it.
TIAX	20	Lower	I twisted it so much something snapped on it. I don't think that one's very good either.
TIAX	21	Lower	Excellent device. The only problem I had, it took a lot of turns to get it to start cinching down. I didn't cinch it down as much as I could. Felt like I occluded blood flow, but there were definitely more turns in that thing, so adequacy of occlusion definitely not an issue as long as that mechanism doesn't fail.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
TIAX	25	Lower	Went on very easy. Tightened the device down on my leg very easy. Start securing device very easily. As I was securing it down, it was getting real tight. I was just about ready to stop and it seemed like the "D" ring loosened up just a little bit. I tightened it down just a little bit more and I stopped from there.
TIAX	27	Lower	Device was very easy to open and get it around my leg. It took a little bit longer to tighten it down than it should have. The handle was kind of smooth and hard to grip, but it didn't slip too much. When I pulled out the top handle it was a little too small to get a grip on. It was an easy device to open and get on my leg and tighten down. Fairly lightweight.
TK-3	1	Upper	It was easy to apply. Seemed to work well.
TK-3	2	Upper	Easy application. Easy securing of device.
TK-3	3	Upper	Tourniquet broke as I was applying it.
TK-3	4	Upper	Works pretty good. It is probably one I would use. The fastener, with a blindfold on is kind of hard to get it hooked the way you want it to, but overall it is a good device.
TK-3	5	Upper	Difficult to place. Training will be required if the patient was blind or without the use of one limb.
TK-3	6	Upper	Initially unraveling the device was a little tricky one-handed. Once I got it off, putting it on the arm was easy and fastening it to the arm was easy.
TK-3	9	Upper	I liked that one. Easy to apply, got nice and tight. No problems to report.
TK-3	10	Upper	Initial application was easy and seemed to get tight enough.
TK-3	11	Upper	I didn't seem to have many problems other than it got hooked on my uniform a couple of times. Other than that it went on fine.
TK-3	12	Upper	That seemed to work just fine. It pinched my skin a little bit when I tightened it up.
TK-3	12	Upper	I thought the device worked very well. It was lightweight and easy to use.
TK-3	13	Upper	Very easy to use.
TK-3	14	Upper	The tourniquet performed well, was easy to apply. Easy to attach.
TK-3	16	Upper	Didn't have any problems with it. Seemed like it went on pretty well. Easy to get tight and overall pretty easy to use.
TK-3	17	Upper	Found it light, simple to apply and use. Except at the end, I had a difficult time burying the hook when there is a lot of fabric from the blouse on your arm.
TK-3	18	Upper	It was fairly easy to apply, but I had difficulty securing it.
TK-3	19	Upper	Liked it, went on easy, definitely stopped circulation.
TK-3	20	Upper	Went on pretty easy, no complaints. It restricted the blood flow. I like this particular one because you can control how much tension just by the rubber band.
TK-3	21	Upper	Device worked well. Had a little difficulty trying to get it on my arm initially and get the hooks untangled, but otherwise worked well.
TK-3	22	Upper	Worked ok.
TK-3	25	Upper	Device went on real easy. Wrapped the device around my arm a bunch of times and secured it. Had a small amount of difficulty trying to secure it. Not too hard though. Secured it. Went on real easy.
TK-3	27	Upper	Easy to open, easy to connect. Very easy to tighten up. I felt

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
			occlusion after the first twist or two. So the rest were just extra. The only thing I found was it was very difficult to get the thing latched with one hand. It would make it easier if there was a little sliding hook.or something to clip into.
TK-3	1	Lower	Applied very easily, seemed to work.
TK-3	2	Lower	Easy application of device. Easy securing.
TK-3	3	Lower	Application was fine, but very dangerous on the snap back someone might end up seriously hurt with slipping of the fingers. Maybe they need to make the fabric better to grip. Application was fine, tightening down was fine, just a dangerous snap back.
TK-3	4	Lower	I like this one but it failed twice. The hook pulled off when I got it tight enough and then when I tried to use it again without the hook and tuck it in, the elastic broke.
TK-3	5	Lower	Application pretty simple. The material slightly slippery, but other than that fairly simple application with 2 hands. Fairly simple to tighten. The strap could maybe be a little bit shorter.
TK-3	6	Lower	Very easy to operate. Pulling it was a little awkward. Fastening was easy and blood flow felt like it was stopped. Best device yet.
TK-3	9	Lower	A very simple one, but a very easy one to use. Got real nice and tight, no problems to report. I like this one.
TK-3	11	Lower	Slippery because it was wet. I had a bit of trouble holding onto it when I was getting it around my leg and I had trouble figuring if I was hooking it into my pants or into the actual tourniquet when I was securing it as the last step.
TK-3	14	Lower	The device worked well, it was easy to implement. My only problem, it was hard to secure.
TK-3	15	Lower	Easy to use, easy to understand and it worked well.
TK-3	16	Lower	No problems getting the thing hooked. It went on pretty easily. It's a little hard to get it tight. You have to stretch it out a good bit to get a good snug fit.
TK-3	17	Lower	It was easy to deploy and wrap, just as difficult to secure.
TK-3	18	Lower	Very hard to handle with sweaty and sandy hands. I had trouble locking it in place. I didn't like it.
TK-3	20	Lower	It was pretty easy. I don't know if it cut off circulation enough. I think you need a stronger material. If you were in a hurry and your leg did get chopped off, you would be running the risk of breaking the rubber band and you would just be stuck.
TK-3	21	Lower	Easy to apply and very compact which is nice. The device stretches and gets pretty tight on the leg, but I don't know if it can actually occlude blood flow in the leg though. At least that's my feeling.
TK-3	22	Lower	Simple to use. Very good.
TK-3	23	Lower	It was easy to apply, quick and simple, but it didn't seem like it put very much pressure. Not hardly as much as the other ones.
TK-3	25	Lower	Device went on very easy. Tightened down as tight as I could get it. Didn't seem as tight as all of the other ones. It went on very easy, the only difficulty was trying to secure it at the end. Since the band was real tight it was kind of hard to try and get the strap underneath the band to try and secure it. I actually attached it to the loop one time and it came off and I had to reattach it underneath the band, but it finally did secure.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
TK-3	26	Lower	I wrapped it around and I could tell it wasn't tight enough so I tried to tighten it and I grabbed the hook to hook it in and the hook came off. I didn't actually pull with the hook I pulled with the rubber then at the end when I tried to hook it in it put all the pressure on that hook and the hook came off.
TK-3	27	Lower	As I was able to get it pretty tight, I am sure of complete occlusion. That was the best tourniquet.
TK-4	1	Upper	It seemed to work well, had a little difficulty in securing it.
TK-4	2	Upper	Easy application of device. Seemed like it got pretty tight. It was somewhat difficult to secure device.
TK-4	3	Upper	It was easy to apply. It was a little slippery on the metal clamps, metal hook.
TK-4	5	Upper	Either the hook was too small or the band was too big. I had a little trouble getting it on one-handed for the first initial loop. Other than that very simple application and no problems.
TK-4	6	Upper	Very easy to apply. Tightening was also done at the same time. It was a little more difficult to use than the TK-3 and getting it fastened with the different fabric was a little tricky.
TK-4	7	Upper	Easy to apply. Even getting it as tight as I could, it still did not feel tight enough. Did find it difficult to secure the hook at the end of tightening. Also feel that troops may end up using it as a bungee cord and it will not be available when needed.
TK-4	9	Upper	Fastened tight, no problems. Had a little bit of trouble securing the hook.
TK-4	10	Upper	It went on easy, but once it is tight it is very difficult to secure, especially with one hand.
TK-4	13	Upper	Worked out just as well as the TK-3. It works out really well.
TK-4	15	Upper	Was pretty easy except at first. It slipped a couple of times. Came loose once and smacked me in the face, but it was pretty easy and pretty effective. I like those kinds of tourniquets.
TK-4	16	Upper	Went on rather easily and seemed to go on pretty tight.
TK-4	17	Upper	Had trouble initially looping the thick elastic through the hook. Had to get it on and do a half twist to it to lock it in. It came off 2 or 3 times before I did that.
TK-4	18	Upper	I was able to get it really tight, but it was hard to fix it in place.
TK-4	20	Upper	Application was pretty easy, much like a TK-3. Looks like it is made of a sturdier material. All in all it still worked the same. I liked that one.
TK-4	21	Upper	Device was slippery when trying to tighten. Unable to tighten to a degree I felt was sufficient. Not an intuitive initial step application. Once again needing to keep the device flat yet maintain a high enough degree of tightness was not easy due to the design.
TK-4	22	Upper	Ok, easy to put on.
TK-4	23	Upper	It was very easy to use.
TK-4	25	Upper	The device went on very easy. Went on tight, definitely stopped the blood flow it seemed. The only difficulty I had was in trying to secure the device. Seemed like it was really hard to get underneath the elastic and there wasn't a lot of play under the elastic. Seemed like I fumbled with that over a minute or so and when I got it secure, it didn't feel like it was really secure.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
TK-4	26	Upper	I still don't like it. It was slippery. It popped off a couple of times while I was trying to put it on didn't seem to put a lot of pressure.
TK-4	27	Upper	It was kind of a pain to get hooked up. I tried to hook it and twist it like I was told, but it kept popping out. I don't think the hooks are round enough or wide enough or some thing. It took me about 5 tries to actually get it connected. Went around my arm, got it pretty tight. Had to use my teeth on the last wrap to hold it so I could slip it under. A ring or some kind of sewn-in device on that end would be beneficial I think to hold it so you wouldn't have to fight it. But at that point you've occluded blood flow anyway so you can take your time. The only thing I think you would have to worry about is if you passed out from shock, then you could let the whole thing go if you didn't get it done in time.
TK-4	1	Lower	It took 2 hands to apply in order to secure it. I thought it worked well.
TK-4	2	Lower	Simple application. Simple securing the device.
TK-4	3	Lower	Application was sturdy.
TK-4	4	Lower	It was kind of hard to apply, the hook kept slipping out. I liked this one because it was light, but I couldn't get it fastened blindfolded sandy and wet. It took me awhile, but I think it occluded.
TK-4	5	Lower	Application was fairly simple. Seemed to get the device fairly tight. The only problem I had was hooking the device to itself at the end because I had it so tight. Didn't take long to get it secured, no problem.
TK-4	6	Lower	Very easy to apply. Pretty painless.
TK-4	7	Lower	Found the device to be simple in concept, but kept slipping when I was trying to wrap it. I found it difficult to get the hook under the tight bands at the end of the procedure, but I do feel like I got it good and tight. Overall, I think it worked pretty well, but I found that I did make some mistakes in the application.
TK-4	9	Lower	This was easy to use. It got nice and tight. I had some trouble hooking the last hook around the band, but other than that no problems to report. I like this one, nice and tight, easy to apply.
TK-4	10	Lower	Hard to secure and did not feel tight enough.
TK-4	11	Lower	Seem to hold really well. The only difficulty I had was latching it when it was all the way around my leg. The final hook is difficult to get between the pants and the tourniquet. Other than that it performed fine.
TK-4	12	Lower	Seemed to work ok, but I felt like I couldn't get it tight enough. Obviously must have worked.
TK-4	13	Lower	It was easy to figure out with my eyes closed. It went on very well. As long as comfort isn't an issue the thing worked great.
TK-4	14	Lower	The device performed well. Was easy to use. Only complaint, it was a little bit difficult to capture after tension was applied.
TK-4	15	Lower	I liked it. It was easy to put on, no problems.
TK-4	16	Lower	Went on easily. Tightened easily and had no problems securing it.
TK-4	17	Lower	I found it simple to apply and wrap. The only difficulty I had was finding a place to bury the hook.
TK-4	18	Lower	I liked it. It got pretty tight, pretty easy to use.
TK-4	19	Lower	Liked it, couldn't get it as tight as the TK-3 but it seemed to lay flatter on my leg. I don't know which one worked better.

TOURNIQUET	SUBJECT	EXTREMITY	COMMENTS
TK-4	20	Lower	Application was very easy, felt like I stopped blood flow, so I liked that one. It was simple. Simple is good.
TK-4	21	Lower	Occluded blood flow very well. Had an issue with it slipping out of the ring the first time because I didn't put the half twist in it. That delayed my application time, because I basically had to start over again. Other than that, the device performed very well. It performed much better on the leg than the arm because you are able to use two hands.
TK-4	22	Lower	Pretty easy to use.
TK-4	23	Lower	Very easy to use.
TK-4	24	Lower	Seemed to work pretty well.
TK-4	25	Lower	Device went on real easy. At first it didn't feel like it was actually getting tightened down enough. By the time I secured the device and laid back, it was definitely tight enough.
TK-4	26	Lower	It was hard to put on, slippery. I probably would have bled to death. Don't like that one at all. Where do you hook it? You have to slide it under the thing. To me, I don't like it at all.
TK-4	27	Lower	Easy to use. The hooks were a little slippery and upon pulling for occlusion I snapped it and it broke.